Some Effects on Wastewater From Brenda Mines on Water Quality, Aquatic Organisms, and Forage Crops

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SOME EFFECTS OF WASTEWATER FROM BRENDA MINES ON WATER QUALITY, AQUATIC ORGANISMS, AND FORAGE CROPS

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EXECUTIVE SUMMARY
BRENDA MINES REPORT

Brenda Mines, a large copper, molybdenum mine, operated in the Okanagan from about 1970 to 1990. The mine site is west of Peachland and south of Kelowna, on the Okanagan side of the height of land, between the Okanagan and Nicola valleys.

This report documents the effects of the mine on local water quality. B.C. Environment sampling results are presented which span the two decades of mine operation. This report describes all the observed effects on water quality, and fish and invertebrates living in waters which received runoff from the mining operations.

Mine operations did change the water quality in streams and Peachland Lake. Most changes in water quality fell within criteria generally used to determine water suitability. There were some exceptions, the most notable of which were for Peachland Lake in the late 1970's when molybdenum slightly exceeded guidelines for human drinking water. The mine recognized the problem and corrected it by diverting contaminated water into the tailings pond. Water quality in the lake has remained suitable for drinking. Molybdenum in water near the mine is frequently above the guideline for irrigation water to be used on crops fed to cattle.

High molybdenum in vegetation fed to livestock can upset their digestive systems causing poor nutrition and health. This study showed that molybdenum concentration in irrigation water did alter the amount of molybdenum in crops. For molybdenum, the most restrictive water quality criterion is not for protecting human health, nor that of aquatic organisms, but for protecting animals such as cows, sheep and deer from excessive molybdenum in their food. Because of the high molybdenum levels around the mine, managing water quality to restrict molybdenum is a challenging environmental task.

No detrimental effects were found on fish or invertebrates living in waters which were affected by Brenda Mines. Metal levels in fish of Peachland Lake were probably increased by the mine, but not sufficiently to stress them. Mine wastewater itself was slightly toxic to fish and invertebrates some of the time. However, Brenda Mines was careful to keep most mine wastes out of flowing waters and consequently, harmful effects on the organisms living in the streams or lakes around the mine were never observed.

Brenda Mines has a large volume of wastewater stored in its tailings pond and pit which could degrade water quality in the Okanagan, an Environmentally Sensitive area. In order to prevent this, both technical and public surveillance committees were established to make ongoing decisions about water quality and quantity management issues. (These committees will be necessary until it has been established what kind of water quantity and quality problems need attention.) This report was written in order to assist with these ongoing tasks of water and waste management.

SOME EFFECTS OF WASTEWATER FROM BRENDA MINES ON WATER QUALITY, AQUATIC ORGANISMS, AND FORAGE CROPS

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TECHNICAL ABSTRACT

Brenda Mines slightly alters water quality both in Trepanier and Peachland creeks and some tributaries. The tailings pond has a slight effect on MacDonald Creek which in turn has a slight effect on Trepanier Creek. Most of the seepage through the tailings dam is captured and returned to the tailings pond by the pumping system operated by Brenda Mines. Very little water from the tailings pond escapes into the Peachland Creek watershed. Before 1980, run-off entered the Peachland Creek watershed from waste rock. This water contained high levels of metals and nitrate. After 1980, a better diversion system was installed and seepage from waste rock was piped to the tailings pond. Molybdenum and nitrate have affected the Peachland watershed and molybdenum exceeds the water quality criterion for irrigation use. Molybdenum concentrations in Peachland Lake decreased after Brenda Mines piped run-off from the waste rock into the tailings pond in 1980.

Tailings wastewater at Brenda Mines was sometimes toxic to aquatic organisms. Other times the wastewater was not toxic, particularly after a mill shut-down had occurred. The tailings wastewater detoxified rapidly, so that after five months the water had no chronic toxicity to *Daphnia*.

Trout downstream of the tailings pond in MacDonald Creek had no increased metal in their muscle or livers. Moreover, their livers were not induced to produce metallothionein, an enzyme which detoxifies metal, indicating that they are not being stressed by high metal levels. In Peachland Lake, however, molybdenum concentration was elevated to some extent in liver tissue and to a much greater extent in muscle tissue. Despite elevated molybdenum, metallothionein was not elevated. Suckers in Peachland Lake seem more subject to metal accumulation than trout, although only three suckers were sampled.

The high molybdenum concentration in Peachland Creek resulted in an unusually high level of molybdenum in grass and alfalfa irrigated with Peachland Creek water.

During the only discharge of tailings wastewater, in the spring of 1984, water quality of Peachland Creek and Okanagan Lake were altered. However, there was no evidence of toxicity to stream invertebrates or fish eggs in Peachland Creek.

PREFACE

The objective of the Waste Management Program is to preserve the quality of the water environment of British Columbia at or above acceptable levels by managing the discharge of pollutants. This report presents information describing some effects of Brenda Mines wastewater seeping from waste rock and the tailings pond. The report documents some effects of the tailings release in 1984. The information is needed in order to provide information to the Public and Technical surveillance committees established to facilitate Brenda Mines abandonment.

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A number of Pollution Control or Waste Management staff assisted with the field work upon which this work is based, but the principal people were R.V. Rattee and D.K. Boyes. Some of the data were collected and analyzed by Brenda Mines Ltd. All staff there were helpful, but I am particularly grateful to F. Pells, D. Perkins and R. Brown. P.W. Jarman, M.J.R. Clark, R. Brown, S. Horvath and L. Swain reviewed and offered suggestions on the manuscript. Most of the typing was done by B. Russell, and the drafting by K. Ballantyne.

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1.0 INTRODUCTION

Brenda Mines is a copper-molybdenum mine located on a divide between Trepanier and Peachland Creek watersheds (Figure 1). The tailings dam is on MacDonald Creek, a tributary of Trepanier Creek. The larger dam backs up tailings water to a secondary saddle dam above the Peachland Creek watershed. Wastewater from the tailings pond seeps under and through both dams. Most of the seepage came from deposition of tailings onto the top of the dam. The fine material in the tailings sealed the pores so that water was retained behind the dam. During periods when the mill was shutdown, the volume of seepage decreased greatly. Most seepage is pumped back into the tailings pond. Some of this wastewater escapes and mixes with the creek water. In the Trepanier watershed, sampling stations are located below the main dam on MacDonald Creek, and on Trepanier Creek upstream and downstream of the confluence with MacDonald Creek.

Surface and groundwater flow through the mine pit and waste rock piles, transporting minerals and blasting residues. Brenda Mines has installed water collection and diversion works to collect contaminated water and direct it into the tailings pond. However, some water escapes so that both surface and groundwater from the mine site enter Peachland Creek and Peachland Lake. In 1980, the height of the tailings pond began to exceed the divide into the Peachland Watershed, so the second (saddle) dam and upper reclaim system was installed. In the Peachland watershed, stations are sampled upstream and downstream from water which flows past the mine.

2.0 RESULTS AND DISCUSSION

2.1 Water Chemistry

2.1.1 MacDonald Creek Watershed

MacDonald Creek is sampled downstream of the tailings dam in a reclaim reservoir and in a settling pond (Figure 1). A "control" site was established (353-- The first four digits of site numbers are common to all, so are usually deleted from referenced to specific sites for the sake of brevity.) which became contaminated by minerals and blasting residues as the waste rock pile expanded. At the reclaim reservoir, water seeping through the dam is pumped back into the tailings pond. In the MacDonald watershed, the concentrations of some constituents were sometimes high at the reclaim reservoir, but most diminished downstream. Cyanide for instance, was elevated in the water of the reclaim reservoir, but downstream cyanide was below detection limits (Appendix Figure 1).

Molybdenum and filterable residue were high at the reclaim dam, but both were lower downstream from the dam (Figure 2 and Appendix Figure 2). Until 1980, Site 353 was downstream of waste rock and blasting chemical used by the mine. Site 353 sometimes had high concentrations of molybdenum and filterable residue. The high values were caused by runoff and leachate from the waste rock as

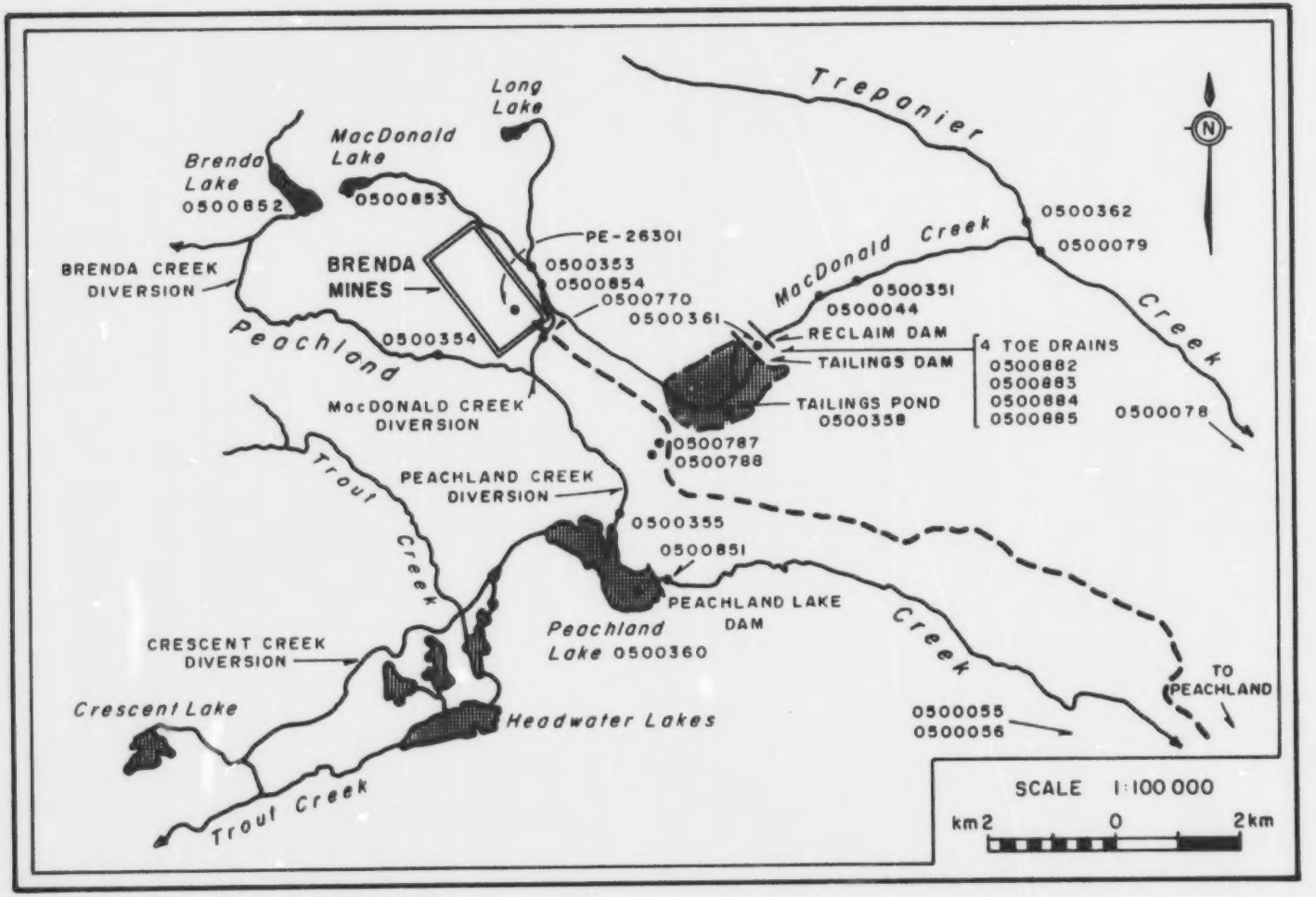
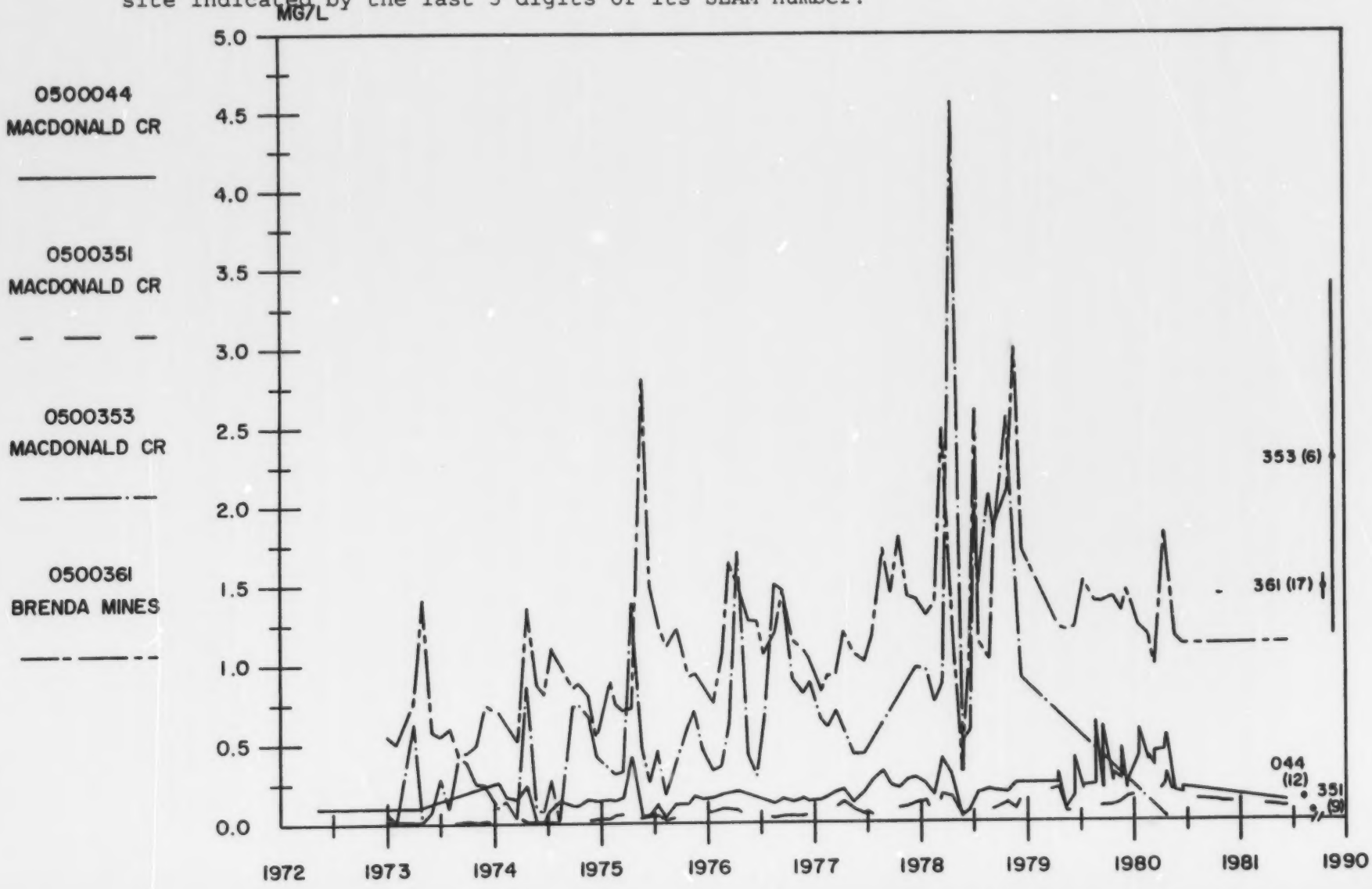


Figure 1 Brenda Mines and locations of sampling sites in Trepanier and Peachland Watersheds.

Figure 2 Dissolved molybdenum concentration (mg/L) in Brenda Mines wastewater and MacDonald Creek. Site 353 was affected by leachate from the waste rock pile which was increasing in size. On the far right is plotted the mean, standard error and/or sample size (n) of all data 1982-90 for each site indicated by the last 3 digits of its SEAM number.



the site is upstream of all tailings. Except for molybdenum, copper, and zinc, other heavy metals were usually below detection limits. Zinc had only a few values above detection limits (Appendix Figure 3). Copper levels in MacDonald Creek apparently were increased by the tailings pond (Table 1), but to a lesser extent than molybdenum; there was no increase in copper concentration of Trepanier Creek.

Figure 3 shows that in the years 1975 to 1978 nitrate was highest at Site 353 where there were values of 5 to 30 mg/L. These high concentrations of nitrate stimulated algae growth downstream. The dense growths of algae occurred at Peachland Lake outlet below the dam (Howard and Walden 1978). The nitrate increased because water flowing through the waste rock piles had picked up nitrogen left from the blasting chemical. To stop the algae growth, Brenda Mines diverted fresh water away from the waste rock piles so that nitrates were no longer leaching to these streams.

The nitrate contaminated water was piped into the tailings pond. The water with high nitrate also contained high levels of dissolved molybdenum. After the diversion, begun in 1979 and completed in summer 1980, nitrate concentrations decreased. For a brief period during spring of 1983 the water was re-diverted into Peachland Creek because the tailings reservoir was nearly full and it became necessary to reduce the volume of stored water to maintain stability of the dam. The water diversion system was restored after freshet 1983.

2.1.2 Trepanier Creek

In Trepanier Creek, monitoring results show a slight influence of tailings leachate from the mine. The concentration of molybdenum was higher in MacDonald Creek than Trepanier (Figure 4). For Trepanier Creek, on 28 of 34 sampling dates, molybdenum levels were higher downstream than upstream of MacDonald Creek ($p<.001$). This analysis used all results including those less than detection which were excluded from Figure 4.

High detection limits reduce the usefulness of samples for molybdenum upstream and downstream of MacDonald Creek. Even though individual values were higher downstream, the mean concentration of dissolved metals was not higher downstream of MacDonald Creek than upstream (Table 1). The mean values are biassed because the detection limits chosen for most samples were too high. As for molybdenum, copper concentrations usually had detection limits inadequate to show any difference which may have existed; hence these results were not used to calculate the mean. The mean values of sulphate and filterable residue in Trepanier Creek have been affected slightly by MacDonald Creek (Table 1; Figure 5). On 25 of 28 sampling dates, sulphate levels were higher downstream than upstream of MacDonald Creek ($p<.001$).

TABLE 1. **Average concentration (mg/L except where specified) and sample size (n) for several parameters in waters around Brenda Mines from 1972-June 1990. Data are means ($\bar{x}$) except for those indicated as medians (med); standard errors are given in Appendix Table 1. The symbol L before a mean indicates that the value includes analyses less than the detection limit so that the true mean would be less than the calculated value. D or T indicates dissolved or total.**

		PEACHLAND				BRENDA MINES	
		Creek Upstream Mine 0500354	Creek Divers. 0500355	Lake by dam 0500360	Creek Highway #97 0500056	Tailing Pond 0500358	Reclaim Reserv. 0500361
pH	$\bar{x}$	7.74	7.67	7.50	8.13	7.95	8.03
	n	107	144	207	250	127	147
Residue Filt	x	79.9	156.8	101.1	200.5	838.0	800.9
	n	96	124	144	151	101	124
Res NF	x	4.37	14.64	6.27	15.58	16.46	59.86
	n	73	108	128	152	111	130
Turbidity (ntu)	x	1.22	4.39	1.23	4.74	8.92	20.2
	n	105	139	154	235	109	136
Cyanide (D)	med	L 0.01	L 0.01	L 0.01	L 0.01	L 0.09	L 0.04
	n	73	1	35	36	87	87
Nitrate + 1109 Nitrite	x	0.046	0.0336	0.098	0.513	3.006	0.296
	n	12	14	18	86	19	21
Phosp Tot D	x	0.064	0.008	0.008	0.013	0.034	0.169
	n	17	14	30	22	17	21
Phosp Total	x	0.016	0.014	0.014	0.040	0.010	0.028
	n	16	17	39	93	16	21
Sulphate (D)	x	7.47	13.9	8.46	21.7	277.5	266.5
	n	23	10	14	43	33	31
Arsenic (D)	med	L 0.01	L 0.25	L 0.25	L 0.25	L 0.01	L 0.08
	n	50	13	8	20	55	57
Cadmium (D)	med	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01
	n	14	12	10	23	20	57
Chromium (T)	med	-	L 0.005	L 0.010	L 0.005	L 0.010	L 0.009
	n		2	18	5	7	4
Copper (D)	x	0.009	0.010	0.004	0.004	0.229	0.027
	n	15	36	32	42	98	40
Molybdenum (D)	x	0.011	0.045	0.103	0.051	0.967	1.193
	n	28	14	70	81	120	121
Zinc (D)	x	0.080	0.015	0.020	0.015	0.030	0.022
	n	2	15	19	20	27	17

TABLE 1 Continued. Average concentration (mg/L except where specified) and sample size (n) for several parameters in waters around Brenda Mines from 1972 to 17 June 1990. Data are means ($\bar{x}$) except for those indicated as medians (med); standard errors are given in Appendix Table 1. The symbol L before a mean indicates that the value includes analyses less than the detection limit so that the true mean would be less than the calculated value. D or T indicates dissolved or total.

		MACDONALD CREEK			TREPANIER CREEK		
		Reclaim Reserv. 0500361	Dnstrm. Reserv. 0500044	Settling Pond 0500351	Upstrm. MacDon. Creek 0500362	Dnstrm. MacDon. Creek 0500079	Highway #97 0500078
pH	$\bar{x}$	8.03	7.93	7.88	8.00	8.01	7.89
	n	147	186	159	148	150	159
Residue	x	800.9	357.7	242.5	100.3	105.9	111.2
Filt	n	124	169	141	127	123	124
Res NF	x	59.86	9.04	3.64	1.75	1.95	5.21
	n	130	149	121	89	92	84
Turbidity	x	20.2	1.57	1.85	0.714	0.68	0.66
(ntu)	n	136	150	110	107	117	138
Cyanide	med	L 0.04	L 0.01	L 0.01	L 0.01	L 0.01	L 0.003
(D)	n	87	87	86	86	87	11
Nitrate	x	0.296	0.090	0.078	0.080	0.065	0.040
+ 1109							
Nitrite	n	21	11	5	10	13	11
Phosp	x	0.169	0.143	0.315	0.176	0.061	0.013
Tot D	n	21	16	12	14	16	21
Phosp	x	0.028	0.012	0.018	0.009	0.009	0.015
Total	n	21	23	12	16	25	41
Sulphate	x	266.5	53.8	36.5	3.73	5.56	5.18
(D)	n	31	50	63	48	45	23
Arsenic	med	L 0.08	L 0.01	L 0.01	L 0.01	L 0.01	L 0.25
(D)	n	57	50	45	48	51	21
Cadmium	med	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01
(D)	n	57	18	45	48	17	28
Chromium	med	L 0.009	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005
(T)	n	4	4	1	3	1	4
Copper	x	0.027	0.012	0.023	0.035	0.028	0.004
(D)	n	40	58	31	15	20	38
Molybdenum	x	1.193	0.198	0.073	0.011	0.010	0.007
(D)	n	121	144	114	31	46	20
Zinc (D)	x	0.022	0.011	0.013	0.015	0.033	0.015
	n	17	26	8	4	7	25

Figure 3 Nitrate concentration (mg/L) in Brenda Mines wastewater, MacDonald Cr, and MacDonald Cr diversion to Peachland Cr (353). Site 353 received water seeping through the wasterock pile which was increasing in size; after 1980, the site was sampled infrequently as the water was piped to the tailings pond. On the far right is plotted the mean, standard error and/or sample size (n) of all data 1982-90 for each site indicated by the last 3 digits of its SEAM number.

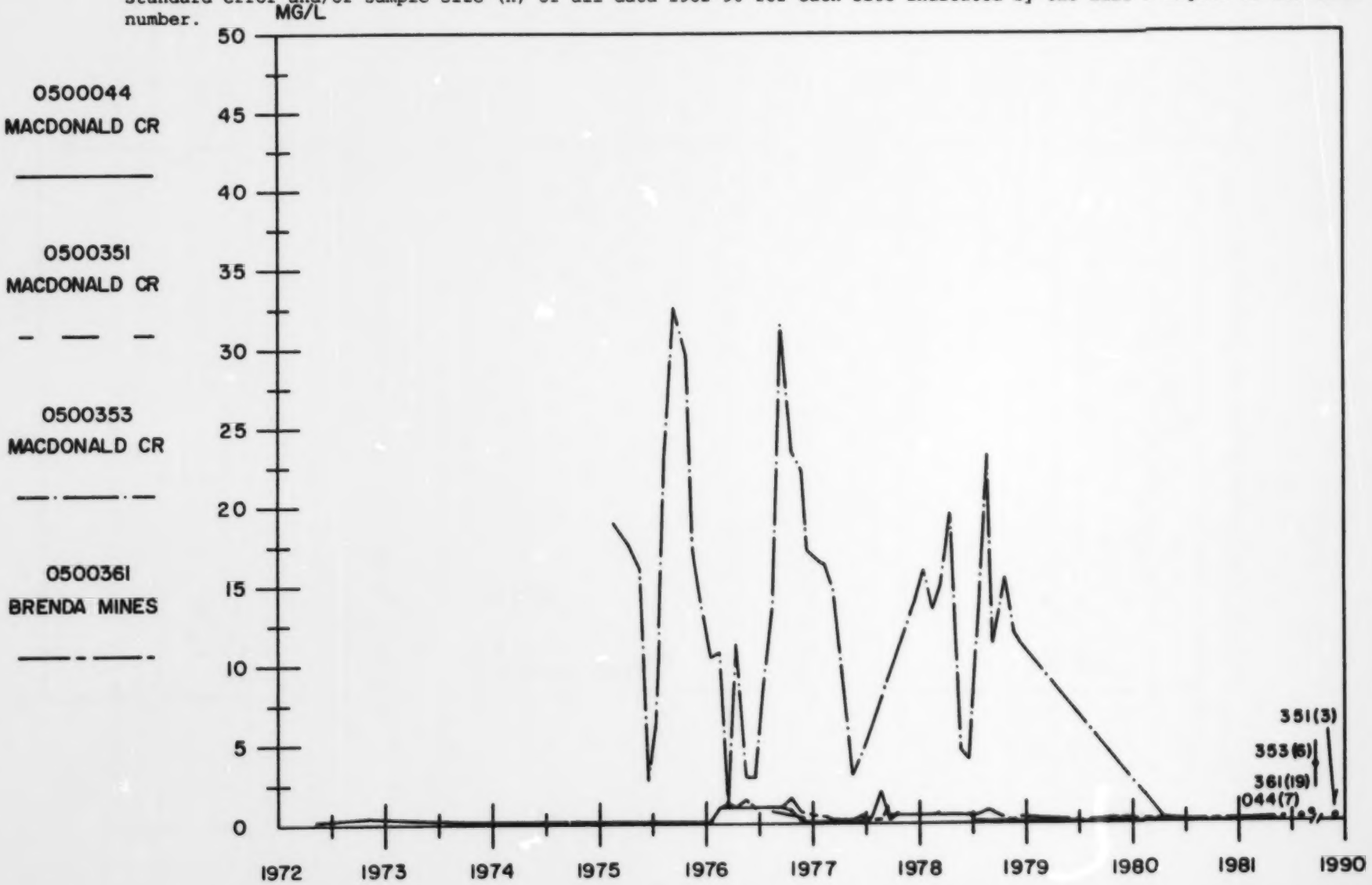


Figure 4. Molybdenum in Trepanier Watershed.

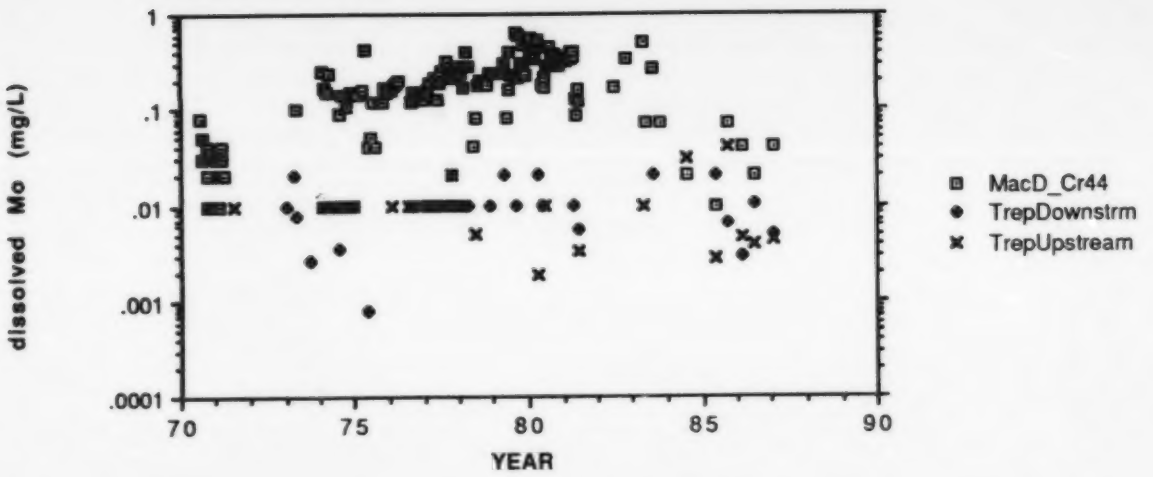


Figure 5. Sulphate in Trepanier Watershed.

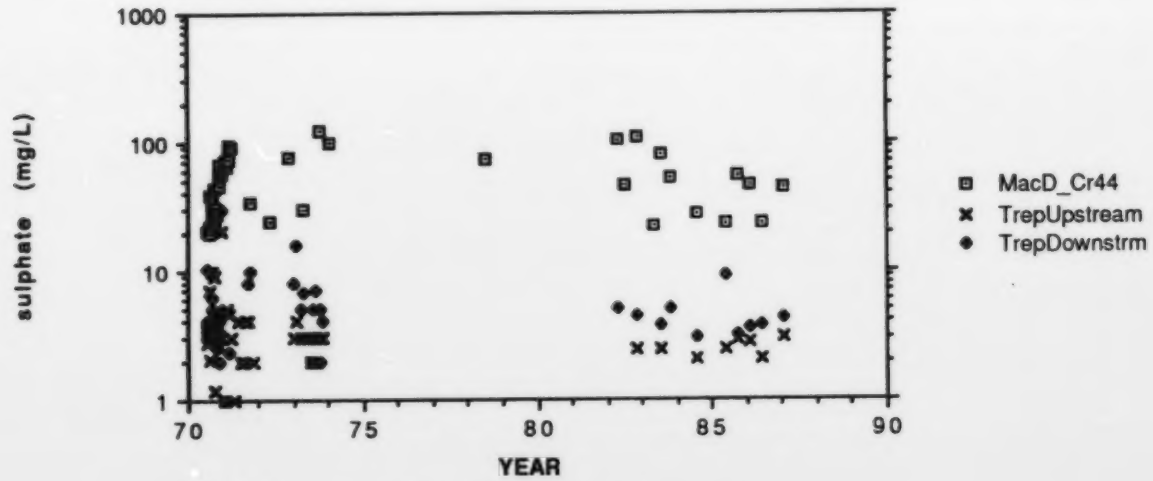
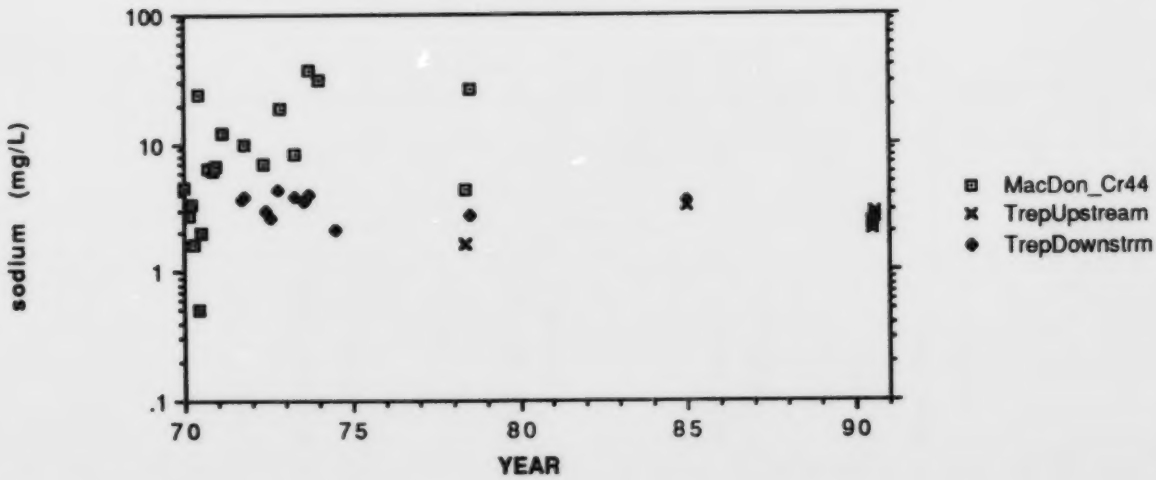


Figure 6. Sodium in Trepanier Watershed.



Sodium in Trepanier Creek appears to be affected by the tailings pond as levels in MacDonald Creek are high and the few available samples suggest a slight rise in Trepanier Creek downstream of MacDonald (Figure 6). For both sodium and sulphate, the levels in MacDonald Creek rose during 1970 as the tailings presumably began to seep into the creek (Figures 5 and 6).

Highest concentrations of most parameters occurred at the mouth of Trepanier Creek (Table 1). Molybdenum was an exception which did not increase below MacDonald Creek (Appendix Figure 4). For most parameters, historic water quality appears to meet water quality objectives (Swain 1990a). However, a monitoring program has been designed in order to be certain (Swain 1990b).

2.1.3 Peachland Creek and Tributaries

In Peachland Creek, nitrate was elevated before 1979, then decreased after Brenda Mines diverted water around waste rock piles during the summers of 1979 and 1980. Since 1980, the nitrate values in Peachland Creek have been reduced. The highest values for most metals, nutrients, and residues occurred near the mouth of Peachland Creek (Table 1).

In Peachland Creek, copper, molybdenum, nitrate, and sulphate are higher at the diversion than upstream of the mine (Table 1). Until 1980, this water was affected by blasting chemicals and rock fragmentation. Peachland Creek was not affected by tailings water until 1980 when the saddle dam was finished and water began seeping under it. In spring of 1983, it received mine runoff and leachate until the diversion and interception system was re-established during the summer.

At their mouths, water quality of Peachland Creek is inferior to Trepanier Creek (Table 1). A number of parameters are much higher in Peachland Creek: turbidity, nitrate, phosphorus, sulphate, and molybdenum. All of these parameters are at least twice as high in Peachland Creek as in Trepanier Creek (Table 1). For molybdenum, the average concentration is 10 times higher at the mouth of Peachland than Trepanier creeks. These differences are relevant because water quality near the headwaters of Peachland and Trepanier creeks is quite similar (Table 1; Sites 354 and 362). Both headwater sites are upstream of all runoff from Brenda Mines. The difference between the mouth of Peachland and Trepanier creeks is thought to result from the historically high molybdenum in Peachland Lake and not from continuing inputs from Brenda Mines. Molybdenum concentrations in Peachland Lake are decreasing, and this trend is expected to continue now that mining operations have creased.

The B.C. water quality criterion for copper in drinking water is 0.5 mg/L (Singleton 1987). Specific objectives have been set for Peachland Creek of about 8 ug/L maximum and 2.4 ug/L average--

the actual objectives depend upon observed hardness (Swain 1990a). Historic data meet these objectives if results which were probably at detection limits are discounted (Swain 1990b).

For molybdenum, the recommended limit for continuous irrigation varies somewhat depending upon soil and crop. The average varies from 0.01 to 0.03 mg/L, and the maximum is 0.05 mg/L (Swain 1986a). For Peachland Creek the objective is maximum 0.05 and average 0.01 mg/L (Swain, 1990a). This objective is applicable during months when irrigation is taking place. The criteria for protecting drinking water is 0.25 mg/L and for aquatic life is 1.0 mg/L (Swain 1986c). Historic data often exeeded objectives for irrigation although recent results are much better.

2.1.4 Peachland Lake

In Peachland Lake, copper and molybdenum are elevated with respect to water upstream of the mine (Table 1). Molybdenum exceeds water quality criteria, whereas copper is below the Canadian drinking water guidelines as well as criteria for B.C. The mean molybdenum concentration in Peachland Lake (0.103 mg/L) exceeds the irrigation limits. However, molybdenum concentrations have decreased since runoff from waste rock piles was diverted out of Peachland Creek Watershed (Figure 7).

Another noteworthy trend in Peachland Lake is for nitrate nitrogen. Figure 8 shows that nitrate levels were high in years when runoff from waste rock was allowed to flow into the lake. Although Figure 8 plots two forms of nitrogen, nitrate (NO_3) and nitrate plus nitrite ($NO_3 + NO_2$), the two measures would normally be equal. This is because nitrite readily combines with oxygen to form nitrate under conditions of high oxygen, which are normal for the epilimnion of Peachland Lake; even the hypolimnion of Peachland Lake has never been observed to have oxygen low enough to inhibit the chemical conversion of nitrite to nitrate. As with molybdenum, nitrate concentrations fell rapidly after seepage and runoff from waste rock were diverted into the tailings pond (Figure 8). In years when nitrate was elevated, nuisance growths of periphyton occurred in Peachland Creek below the dam for Peachland Lake.

Other water quality characteristics of Peachland Lake are presented in the Appendix (Figures 5 to 13). Although some of them show seasonal fluctuations, none show strong year to year trends. Sodium, and sulphate levels were low and without trend (Appendix Figures 8, 9). Copper sometimes exceeded the objectives for protecting aquatic life (Appendix Figure 7), although this did not stress the fish as discussed elsewhere (Section 2.3.2).

Figure 7. Molybdenum in Peachland Lake.

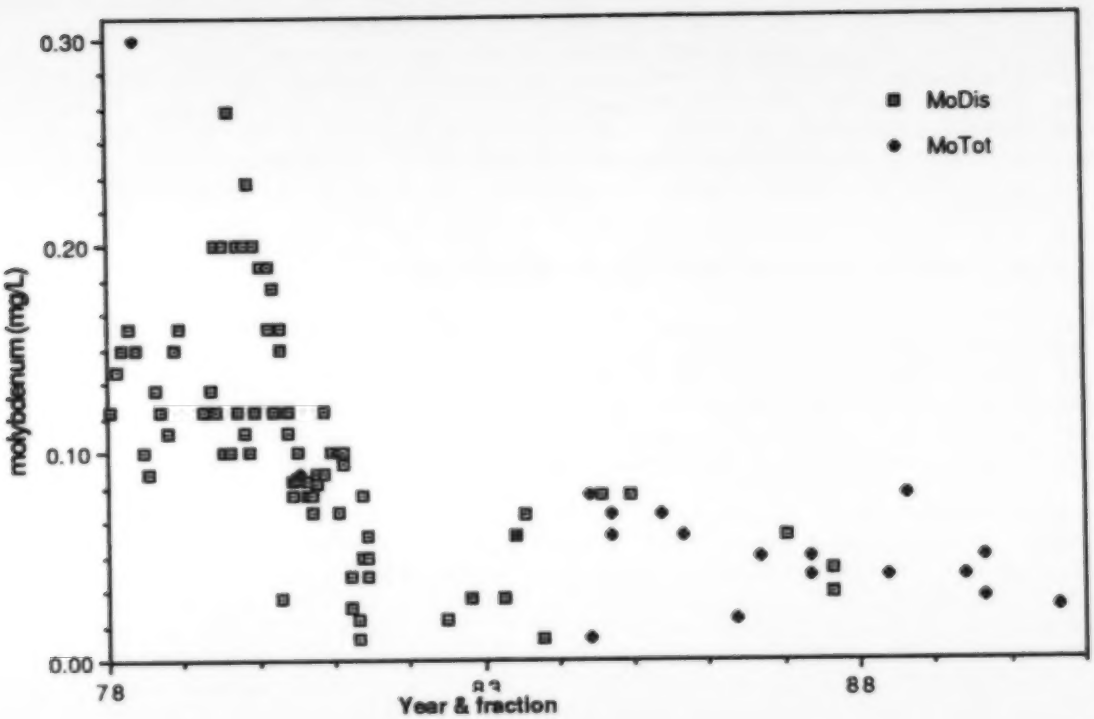
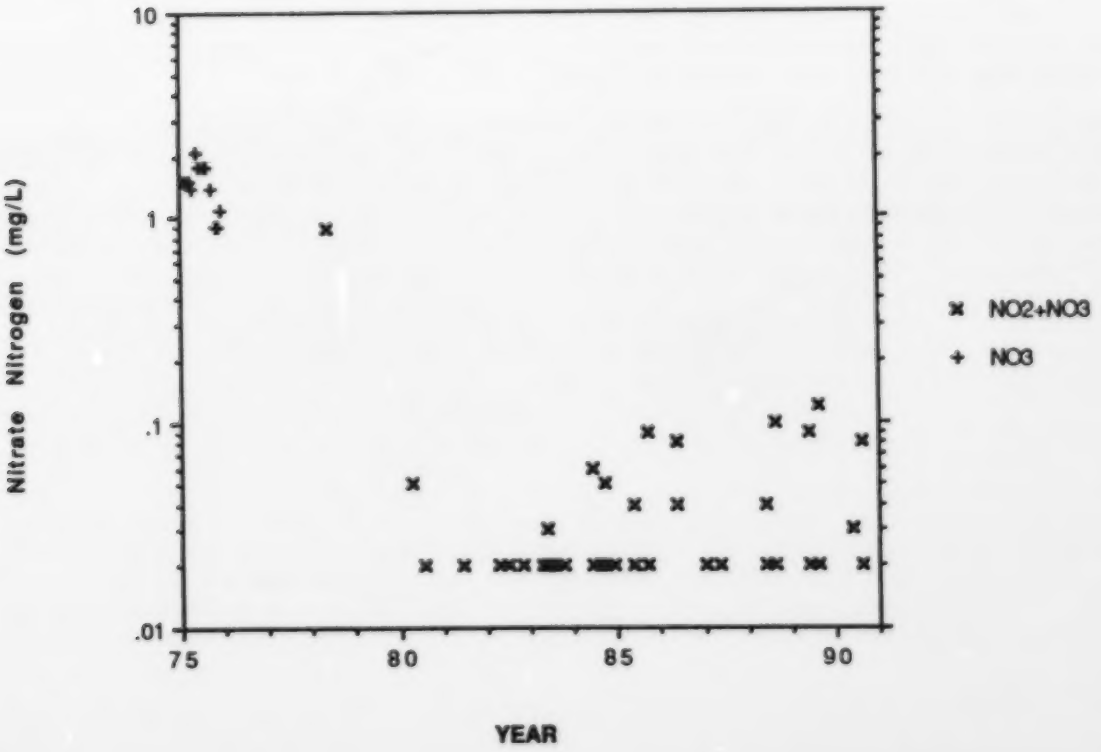


Figure 8. Nitrate and nitrate + nitrite in Peachland Lake.



2.2 Toxicity Tests of Mine Waste & Receiving Water

2.2.1 Bacteria Bioassay

Samples were taken for bacteria bioassay on ten dates (Table 2). For no sample was the wastewater toxic to the bacteria. Even the undiluted effluent had no toxicity associated with it. Wastes are often toxic to some organisms but not others. Consequently, toxicity monitoring usually involves several kinds of test organisms.

2.2.2 *Daphnia* and Rainbow Trout Bioassay

Table 3 shows bioassay results with *Daphnia*. *Daphnia* are small crustaceans which live in the water column of ponds and lakes. The adult *Daphnia* range in size from about 1 to 5 mm long. They eat phytoplankton and swim by moving appendages resembling arms. *Daphnia* can be cultured readily in a laboratory, so are convenient organisms for measuring toxicity.

Brenda Mines shut down from mid-September 1983 to mid-May 1984. When the mine was shut down there was no acute toxicity to *Daphnia* (Table 3). Using water collected February 21, 1984, a chronic toxicity test was also done with *Daphnia*. In the chronic test, *Daphnia* were reared in Brenda Mines tailings water for 21 days, which is long enough for them to produce young. The growth rate of the *Daphnia* cultured for this time period in tailings water was equivalent to the growth rate of *Daphnia* cultured in control water without mine waste. In addition, the number of offspring produced by the *Daphnia* in the tailings pond water was no different from the number produced by *Daphnia* cultured in water not affected by mine wastes. Thus the chronic bioassay showed that there was no chronic toxicity of the mine wastewater in February 1984. At this time the mine had ceased operating for several months. No pickling liquor had been added to the tailings pond since November 1983. We would therefore expect low toxicity after mine closure.

When the mine resumed operation and the chronic *Daphnia* bioassay was repeated on June 6, however, there was both acute and chronic toxicity as a result of the tailings water. In the June 6 tests, even mine wastewater diluted to 30% of the original volume still resulted in chronic and acute toxicity. The acute toxicity of the diluted water, however, was less than the acute toxicity of the undiluted tailings water at this time. The dilution required to render the tailings non-toxic on June 6 was not determined. This toxicity was not due to pickling liquor as none was added to the tailings pond until July 1984.

TABLE 2. Microtox bacteria bioassay of Brenda Mines tailings and water potentially affected by tailings. The data indicate when and where tests were done with undiluted water. Tests were light reduction usually after 15 minutes (15EC50), but on two occasions (June 81 and July 82) after 5 minutes (5EC50). All tests showed no effect (NE) and dashes indicate sites not sampled, when others were.

Sample Site Description	Jun 81	Apr 82	Jul 82	Oct 82	Feb 82	Apr 83	Jul 83	Oct 83	May 83	Sep 83
Tailings pond (PE-363)	NE	-	-	-	-	NE	NE	NE	NE	NE
MacD C reclaim (361)	NE	NE	NE	NE	NE	NE	NE	-	NE	NE
MacD C DNS Reclaim (044)	NE	NE	NE	NE	-	-	-	-	-	-
MacD C Sett (351)	NE	NE	NE	NE	-	-	-	-	-	-
MacD C UPS Dvr (353)	NE	-	-	-	NE	-	-	-	-	-
Trep C DNS MacD (362)	NE	NE	NE	-	-	-	-	-	-	-
Trep C UPS MacD (079)	NE	NE	NE	NE	-	-	-	-	-	-
Pchld C mouth (055)	NE	-	-	-	-	-	-	-	-	-
Pchld C UPS Dvr (355)	NE	-	-	-	-	-	-	-	-	-
Pchld C UPS Mine (354)	NE	-	-	-	-	-	-	-	-	-
Pchld C Reclaim (787)	-	NE	NE	NE	-	NE	NE	-	NE	NE

When the mill at Brenda Mines was operating, the tailings water was sometimes acutely toxic to *Daphnia* (Table 3). For instance in April and July 1983 and in June 1984, there was acute toxicity to *Daphnia* in the tailings water. At other times, however, there was no acute toxicity to *Daphnia* kept in tailings water as in October 1982 and July 1984.

Water seeping from the tailings dam also varied in toxicity to *Daphnia* (Table 3). In April and July 1983, the seepage water was less toxic than the tailings pond water itself. The reduced toxicity might be expected since the tailings water must pass through an earth filter in order to reach either the upper or the lower reclaim reservoir. The lower reclaim reservoir has greater depth of tailings and slime for seeping water to pass through. There is also a greater volume of water entering the lower reclaim reservoir since it is the main dam on the tailings pond.

TABLE 3. Percentage mortality of *Daphnia* during standard bioassay tests of Brenda Mines wastewater. The tailings water flows into the tailings pond whereas the reclaim water has passed through the upper or lower tailings dam. Dashes indicate that no sample was collected. On two occasions (*) rainbow trout bioassays were also performed without any mortality after 96 hr.

Sample Site	1982 Oct 26	1983 Feb 21*	1983 Apr 13	1983 Apr 21	1983 Apr 27	1983 July 27
Tailings Pond (358)	0%	-	-	100%	100%	40%
Pchld C Reclaim (787)	0%	-	0%	-	-	10%
MacD C Reclaim (361)	0%	10%*	50%	0%	100%	0%
MacD C Ups Dvr (353)	-	0%	-	-	-	-

Sample Site	Mill Shut Down 1983 Oct 13	1984 Feb 21*	1984 June 6	1984 July 25	1986 Feb 10	1987 Jan 20
Tailings Pond (358)	0%	0%*	40%	0%	0%	0%
Pchld C Reclaim (787)	0%	-	-	0%	10%	0%
MacD C Reclaim (361)	0%	-	-	0%	-	0%

The upper reclaim reservoir is located at the toe of the much smaller, secondary saddle dam that was placed behind the tailings pond as the pond rose enough to start impinging on the Peachland Creek watershed.

As indicated in Table 3, the tailings were not always toxic to rainbow trout (*Oncorhynchus gairdneri*). During the 1983 to 1984 shutdown, trout were kept in cages suspended in the tailings pond. All of these trout survived for nine days living in the tailings water in February 1984. After nine days some caged trout died, and all the rest died within twenty days. After these fish were removed from the tailings pond they were dissected, their livers submitted for analysis of metallothionein and heavy metal content. Livers of control trout (not held in the tailings pond) were also submitted for such analysis. Harding (1987) claims that results of the tests showed no effect of tailings; however, no data are presented to support this claim.

No trout mortality occurred in standard toxicity tests but only once were trout tested when there happened to be toxicity to *Daphnia*. Trout mortality did occur in the tailings pond but only after 9 days (standard acute toxicity tests are 4 days); even then excessive handling probably contributed to the mortality (Harding 1987). Toxicity tests were not conducted routinely on trout because of the cost, large volume of water required, and a reluctance to use trout for that purpose. For mine waste, *Daphnia* are a good substitute for trout because they usually show similar test results (Steve Horvath, personal communication). Therefore, there is little doubt that the wastewater would have been toxic to trout as well as *Daphnia* had trout tests been performed on days when significant *Daphnia* mortality occurred such as April 1983. Even so, there were times when the tailings had no acute or chronic toxicity. Tailings from another copper-molybdenum mine (Island Copper) also have low toxicity to rainbow trout or coho salmon (Waldichuk and Buchanan 1980).

2.3 Effects of Metals on Fish

2.3.1 Metal Content of Rainbow Trout Tissues

F.S. Pells, Hydraulics Supervisor at Brenda Mines, collected some rainbow trout from the Settlement Pond in MacDonald Creek and had the muscle tissue tested for heavy metals. Table 4 shows the results of these tests. The trout had been stocked into the Settlement Pond during the summer of 1975. Metal determinations were done by B.C. Research mainly with atomic absorption spectrophotometry.

With minor exceptions, these metal concentrations are similar to those for fish from some watersheds of Northern Canada. The values are similar to those for fish in the Northern Yukon (Bryan *et al*. 1973), but somewhat higher than in fish of the Mackenzie watershed (Hatfield *et al*. 1972). Except for mercury, the metal concentrations were also similar to those of rainbow trout from the Fraser River (Swain 1986c; Singleton 1983). Mercury concentrations were higher in trout from the Fraser River than trout from MacDonald Creek (Singleton 1983).

In 1983, additional specimens were collected and their tissues submitted for analysis of metal. In the Settlement Pond, three trout were captured in March and April by Brenda Mines staff using hook and line. The two others from the Settlement Pond and all fish from Peachland, Brenda, and MacDonald Lakes were captured by B.C. Environment staff using gill nets set in early May 1983.

Tissue analysis was performed on rainbow trout from four sites to determine effects of metals from the tailings pond and waste rock runoff from Brenda Mines (Figure 1). Water from Brenda Lake flows into Peachland Lake, so fish from Brenda Lake serve as controls for those from Peachland Lake. Likewise MacDonald Lake flows into MacDonald Creek, and fish from MacDonald Lake serve as controls for those from the Settlement Pond. Fish from the lakes had presumably grown up in the same water from which they were

captured; however fish in the Settlement Pond had been transplanted. It was rumoured that they had been transplanted from a creek flowing into Peachland Lake in 1975, eight years before they were sampled. The average size of the trout in the Settlement Pond was approximately 3 times greater than the average size of trout from the other water bodies. These trout had grown considerably since being transplanted from the Peachland watershed into the Settlement Pond.

Table 5 shows that trout collected from water receiving runoff or seepage from Brenda Mines did not have elevated metal levels in their livers. None of the metal levels for trout from water affected by the mine were more than two standard errors (SE) greater than the controls. In a few instances the controls were significantly greater. Brenda Lake trout, for example, had copper and cadmium levels considerably greater than those of Peachland Lake trout.

2.3.2 Anti-Metal Enzyme in Rainbow Trout

Fish livers respond to high metal levels by producing an enzyme, metallothionein, which detoxifies metal (Roch, *et al.* 1982). Thus fish exposed to dangerous levels of metals usually have elevated levels of metallothionein in their liver. Table 5 shows that metallothionein of trout from lakes affected by Brenda Mines did not differ from the control lake in the metallothionein concentration of their liver. Buttle and John Hart Lakes have been affected by wastewater from a copper, lead, zinc mine which greatly increased the metal concentration of the water (Roch, *et al.* 1982). Table 6 also shows that the metallothionein content of trout from Buttle or John Hart Lakes is considerably higher than in trout from either Peachland Lake or the Settlement Pond. This was true of Peachland Lake even though copper sometimes exceeded objectives for protecting aquatic life (Appendix Figure 7).

Fish liver is an appropriate organ for measuring metal content since most literature on metal concentration in fish has been done for liver tissue. Although liver tissue usually contains higher levels of heavy metals than does fish musculature, it is appropriate to sample fish musculature as muscle is the part of the fish actually eaten by humans catching the fish.

TABLE 4. Metal composition in musculature of rainbow trout captured in the Settlement Pond of MacDonald Creek. The trout ranged in size from 197g to 331g (255 to 305 mm fork length). Data were provided by Brenda Mines.

	WET WEIGHT		
	Date Caught		
Test	22 Feb. 1979	28 Feb. 1979	28 Feb. 1979
Copper (ug/g)	0.65	0.85	0.85
Zinc (ug/g)	4.60	6.05	6.25
Cadmium (ug/g)	L0.25	0.50	L0.25
Lead (ug/	L1.0	L1.0	L1.0
Molybdenum (ug/g)	L1.0	L1.0	L1.0
Mercury (ug/g)	0.04	0.03	0.02
Moisture (%)	73.5	75.4	73.4

	DRY WEIGHT		
Metal	Date Caught		
(ug/g)	22 Feb. 1979	28 Feb. 1979	28 Feb. 1979
Copper	2.45	3.46	3.20
Zinc	17.4	24.6	23.5
Cadmium	L1.00	2.03	L1.00
Lead	L4.0	L4.0	L4.0
Molybdenum	L4.0	L4.0	L4.0
Mercury	0.15	0.10	0.08

TABLE 5. Average metal concentration (ug/g) of all rainbow trout captured from four locations near Brenda Mines in Spring 1983. These data are dry weight of liver tissue. Control Lakes indicated by *.

	PEACHLAND LAKE (n=22)		BRENDA LAKE* (n=19)		SETTLEMENT POND (n=5)		MACDONALD LAKE* (n=20)	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Copper	69.3	13.4	172.3	35.2	30.6	19.0	49.7	8.7
Zinc	118.5	6.8	131.7	4.7	75.8	10.7	110.6	5.8
Lead	2.4	0.23	2.2	0.18	1.3	0.20	3.0	0.41
Mo	3.0	0.39	2.4	0.21	3.8	0.97	2.5	0.34
Cd	2.1	0.25	4.2	0.35	1.2	0.20	4.	0.36

TABLE 6. Average metallothionein (nmol/g, wet weight) level in livers of rainbow trout captured in different waters in Spring 1983. Control lakes indicated by *.

Water Body	Average	Sample Size	Standard Error
Brenda Lake *	29.6	5	1.33
Peachland Lake	22.4	7	3.18
Settlement Pond	34.7	7	6.65
POOLED	**28.8**	**19**	**2.88**
John Hart Lake	94.	5	8.05
South Buttle Lake	269.	5	10.29
Upper Quinsam Lake *	58.	5	6.26

2.3.3 Metal Content of Rainbow Trout Muscle

Table 7 shows metal concentration in trout musculature for the same water bodies as Table 5. The molybdenum content of Peachland Lake trout muscle was significantly greater than Brenda Lake trout muscle (Table 7). The other metals in trout living in waters receiving wastewater from Brenda Mines were not elevated. Trout in the Settlement Pond for instance had molybdenum levels that were the same as those from MacDonald Lake and similar to those in Brenda Lake. The concentrations of copper and to a lesser extent zinc, were elevated in MacDonald Lake trout. This is an interesting anomaly but presumably not an effect of Brenda Mines as no wastewater from the mine can reach MacDonald Lake. The copper and zinc levels of fish from the Settlement Pond seem higher in 1983 than 1979, although the level of other metals do not (Tables 4 and 7).

Metal concentration of fish tissue may be related to fish size. Larger fish eat more food therefore getting more metal in their bodies. It is reasonable to think that perhaps the concentration of metal per unit of body tissue increases as the fish grows. To eliminate this possibility, metal concentration could be regressed on the fish size. The resulting regression lines could then be compared for fish taken from the different waters. When data on metal concentration and fish size were plotted, there was no obvious relationship between fish size and copper or molybdenum content. Therefore, no attempt was made to perform a regression of metal concentration against fish size. Other workers have found that some metals (copper, iron, and manganese) are accumulated independently of fish size whereas mercury is not (Singleton, 1983; Anon. 1989).

TABLE 7. Average metal concentration (ug/g, dry weight) of all rainbow trout captured from four locations near Brenda Mines in Spring 1983. These data are dry weight of muscle tissue.

	PEACHLAND LAKE (n=22)		BRENDA LAKE* (n=19)		SETTLEMENT POND (n=5)		MACDONALD LAKE* (n=20)	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Copper	1.8	0.3	1.6	0.2	1.8	0.3	3.4	0.2
Zinc	23.3	4.0	16.0	0.3	16.5	1.5	30.9	7.1
Lead	1.3	0.3	1.1	0.1	1.0**	0.0	1.7	0.3
Mo	1.9	0.3	1.0	0.1	1.2	0.2	1.2	0.1
Cd	1.0**	0.0	1.0**	0.0	1.0**	0.0	1.0**	0.0

* Control lakes.
** All values less than detection limits.

The elevated molybdenum levels in trout musculature from Peachland Lake probably has biological meaning. Molybdenum was slightly elevated in trout livers as well (Table 5) although this difference is not significant in the statistical sense. Because the metallothionein of trout livers in Peachland Lake was not elevated, the molybdenum presumably did not cause stress in these fish. The unusually high molybdenum in Peachland Lake water probably caused the increase in molybdenum of the trout muscle. As shown in a previous section of the report molybdenum concentration in Peachland Lake water was high and exceeded irrigation water objectives.

2.3.4 Metals and Anti-metal Enzyme in Suckers

Peachland Lake was the only water body near Brenda Mines known to contain fish species other than rainbow trout. Three longnose, or fine scaled, suckers (*Catostomus catostomus*) were captured in Peachland Lake with the same nets as the rainbow trout and submitted for tissue analysis of metal and metallothionein content. Molybdenum was slightly higher in muscle and significantly higher in liver than in the respective tissue of trout (Table 8). Zinc in muscle and cadmium in liver were also elevated in sucker tissue. The metallothionein content of sucker liver was not elevated indicating that metals were not sufficiently high to induce its production and that the suckers were not under metal stress. The elevated metal content of sucker tissue may reflect the difference in diet between suckers and trout; alternatively, it may reflect the small number or limited size distribution of suckers sampled. Singleton (1983) also found that molybdenum was high in longnose suckers.

TABLE 8. Metal and metallothionein content of sucker tissue from Peachland Lake in May 1983. Three suckers were captured and sampled; their fork lengths ranged from 318 to 328 mm. The data are in ug/g dry weight for metals and nmol/g wet weight for metallothionein.

Metal	Muscle		Liver	
	x	SE	x	SE
Copper	2.3	0.67	49.7	0.33
Zinc	70.3**	0.88	133.7	12.17
Lead	1. *	0	2.	0.58
Molybdenum	2.	0.58	6.3**	0.33
Cadmium	1. *	0	6.3**	0.33
Metallothionein			28.0	5.29

* All values less than detection limits.

** Exceed averages for Peachland Lake trout by more than 2 SE

There is no evidence that the rainbow trout in the Settlement Pond reproduced. This was presumably because MacDonald Creek upstream of the pond was very shallow, offering little or no suitable spawning habitat.

2.4 Effects of Metals on Plants

To determine whether irrigation water affects metal content of vegetation, samples were collected from different farms irrigated with water from either Peachland Creek or Trepanier Creek. From each field, grass or alfalfa was snipped in three areas and stuffed into tissue cups. These vegetation samples were tested for molybdenum and other metals. The data for molybdenum and copper have been examined.

In the case of copper, there was no difference in concentration of vegetation which had been irrigated with Trepanier or Peachland Creek water. The average concentration of copper for vegetation irrigated by Trepanier Creek was 10.3 ppm and that for Peachland Creek 8.7 ppm. In the case of molybdenum, however, Table 9 shows that there was a significant difference in the molybdenum content of vegetation irrigated by the two creeks. In the analysis of variance, CREEK makes a significant difference to the outcome. Table 10 shows that molybdenum in vegetation irrigated by Trepanier Creek was only 14.3 ppm whereas the average for Peachland Creek was 28.8 ppm. Vegetation type did not affect the analysis even though legumes, such as alfalfa, sometimes accumulate molybdenum more readily than non-legumes (Swain 1986b).

TABLE 9. Analysis of variance of molybdenum level in vegetation by type (grass or alfalfa) irrigated with water from Peachland or Trepanier Creeks. The grass and alfalfa was sampled in August 1984. The data are molybdenum concentrations in ppm (ug/g dry weight).

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	p
Main Effects	701.	2	350.	4.5	0.048
Creek	631.	1	631.	8.2	0.021
Vegetation Type	70.	1	70.	0.9	0.371
2-Way Interaction:	37.	1	37.	0.5	0.515
Creek x Vegetation Type	37.	1	37.	0.5	0.515
Explained	738.	3	246.	3.2	0.084
Residual	617.	8	77.		
TOTAL	1,355.	11	123.		

TABLE 10. Average concentration (ppm dry weight) of molybdenum in grass, alfalfa, or both irrigated with Trepanier or Peachland Creek water. Twelve samples were collected in August 1984.

CREEKS	VEGETATION TYPE		
	GRASS	ALFALFA	BOTH GRASS & ALFALFA
Trepanier	15.00	13.67	14.33
(n)	(3)	(3)	(6)
Peachland	33.00	24.67	28.83
(n)	(3)	(3)	(6)

The molybdenum content of the water was higher in Peachland Creek than in Trepanier (Table 1). On the date when the samples were collected, molybdenum in Peachland was 0.05 mg/L whereas the concentration in Trepanier was only 0.0047 mg/L. The concentration of molybdenum was also measured in the irrigation system of the respective farms from which samples were collected, and these concentrations agreed well with those collected at the mouth of each creek. Table 1 shows that the average molybdenum concentration of the two creeks is similar to that obtained on the day when samples were collected. Leaves of cherry trees irrigated with both water sources were also sampled. Most of these samples however turned out to have molybdenum of less than 1 ppm which is the lab detection limit. Consequently these data

were not useful in determining whether irrigation water makes a difference to molybdenum concentration of cherry trees and were omitted from the analysis of variance.

Grass and alfalfa irrigated with Peachland Creek water contain significantly higher levels of molybdenum than those irrigated with Trepanier Creek water. Vegetation irrigated with either water supply, however exceeds the levels that are recommended for hay fed to cattle. The levels are not absolute and depend partly upon copper concentration as well as other constituents such as sulphate. A rule of thumb is that a ratio of copper: molybdenum greater than 2:1 is desirable to prevent copper deficiency (Miltmore and Mason 1971). For Peachland and Trepanier vegetation, these ratios are 0.3:1 and 0.72:1 respectively. Therefore, copper deficiencies would seem possible in cattle fed this hay unless copper supplements are provided.

2.5 Effects of Tailings Pond Drawdown 1984

Tailings water was released into Peachland Creek February 22 to April 16, 1984. To document the effects, water samples were collected from Peachland Creek and Okanagan Lake at frequent intervals by Brenda Mines personnel and various Waste Management staff. In addition, some water samples were collected weekly at the mouths of Peachland and Trepanier creeks just before entry into Okanagan Lake.

2.5.1 Effect on Invertebrates and Fish Eggs

Samples of kokanee alevins incubating in Peachland Creek gravel were collected before and after tailings release by D.L. Jones of Fish and Wildlife Branch. Although few eggs or fry were collected, the survivorship in Peachland Creek was similar to that of Trepanier Creek indicating that there was no direct toxicity. Details are given by Harding (1987) who points out that increased flow affected young kokanee. Benthic macroinvertebrate samples were collected in Peachland Creek and Trepanier Creek before and after the release of wastewater.

Macroinvertebrates were collected using a Waters and Knapp (1961) sampling device. It sampled an area of 0.09 m^2 with mesh opening of 0.5 mm. In each creek, six samples were collected before and six after the tailings release. The totals of the six samples are given in Table 11.

Most kinds of benthic invertebrates occurred at the mouth of Peachland Creek, both before and after the release tailings (Table 11). The total number decreased after the discharge (39%). However, the total number dropped the same extent (38%) in Trepanier Creek, which was not affected by the release. In both creeks there were about the same number of kinds of invertebrates before as after, although for both creeks the taxa collected differed slightly between the two times. Had the tailings wastewater been particularly toxic, some of the taxa such as mayflies and stoneflies would have been greatly reduced

after the tailings release into Peachland Creek but not Trepanier Creek. Because no taxa were reduced or eliminated in Peachland Creek, the mine waste was not very toxic (if toxic at all). Moreover the extra water quantity did not affect the benthic invertebrate populations.

TABLE 11. Total number of benthic invertebrates captured in six samples near the mouth of Peachland or Trepanier Creeks before (February 13, 1984) and after (March 13, 1984) release of tailings water from Brenda Mines.

	PEACHLAND CREEK		TREPANIER CREEK	
	BEFORE	AFTER	BEFORE	AFTER
ORGANISM				
Baetidae	131	42	364	117
Baetiscidae	43	0	0	0
Brachycentridae	0	0	0	5
Capniidae	0	0	14	24
Ceratopogonidae	0	1	0	0
Chironomidae	17	11	377	158
Chloroperlidae	5	7	34	11
Collembola	2	1	0	0
Elmidae	33	28	29	33
Empididae	0	1	0	1
Ephemerellidae	12	0	0	0
Ephemeridae	25	7	18	5
Heleidae	1	3	0	0
Heptageniidae	55	19	126	129
Hirudinae	0	2	2	0
Hydropsychidae	55	17	6	1
Leptoceridae	38	2	0	0
Nemouridae	11	0	941	162
Oligochaeta	94	15	84	98
Perlidae	2	2	0	0
Perlodidae	0	0	3	0
Perlopidae	2	0	0	0
Planariidae	18	12	0	0
Psychodidae	5	2	2	2
Psychomyiidae	0	6	0	1
Rhyacophilidae	38	61	6	3
Simuliidae	1	1	13	1
Taeniopterygidae	11	3	49	24
Tipulidae	7	2	1	1
TOTAL	606	245	2069	776

2.5.2 Effect on Okanagan Lake

Water quality was sampled in Okanagan Lake near the mouths of Peachland and Trepanier Creeks. Both sites were sampled at the same depth (12 m). However the Trepanier Creek site had a much steeper dropoff than the Peachland Creek site; consequently the Trepanier site was closer to the creek mouth than the Peachland Creek site. The Trepanier Creek site was approximately 50 m away from the mouth of the creek whereas the Peachland Creek site was approximately 250 m from the mouth of the creek. Water samples were collected with a tygon tube which extended from the water surface to 10 m.

Several water quality characteristics typical of the tailings pond wastewater increased at the mouth of Peachland Creek during the tailings discharge to a greater extent than at Trepanier Creek. For example, molybdenum, chlorophyll, sulphate, specific conductance and sodium (Figures 9 - 13) increased near the mouth of Peachland Creek. Figure 10 suggests that phytoplankton populations in Okanagan Lake may have been stimulated by the tailings release but the data are few and perhaps spurious. Other parameters (phosphorus, copper, iron, ammonia and nitrate) did not show an effect of the tailings release (Figures 14 - 19).

On two occasions the plume of wastewater was sampled in Okanagan Lake near the mouth of Peachland Creek. The plume was sampled by taking transects at angles to the mouth of Peachland Creek. Along each transect the conductivity of the water generally decreased away from the mouth of Peachland Creek. Once the main tail of the plume extended south along the shore of Okanagan Lake. On the other occasion, the tail of the conductivity plume extended north along the shore of Okanagan Lake. On both sampling days the lake was relatively calm so presumably the water current had been set up on previous days when there had been a wind.

FIGURE 9. Total Molybdenum in Okanagan Lake near creek mouths.

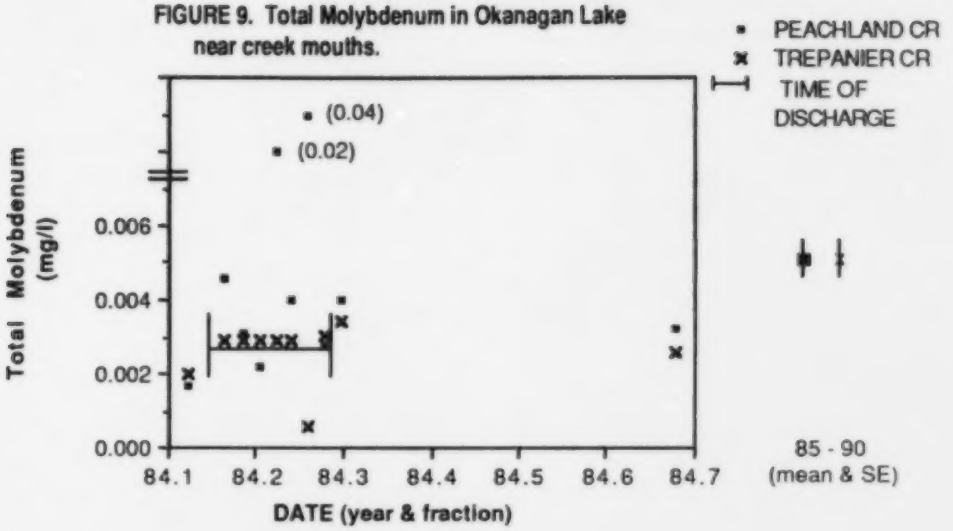


FIGURE 10. Phytoplankton Chlorophyll "a" in Okanagan Lake near creek mouths.

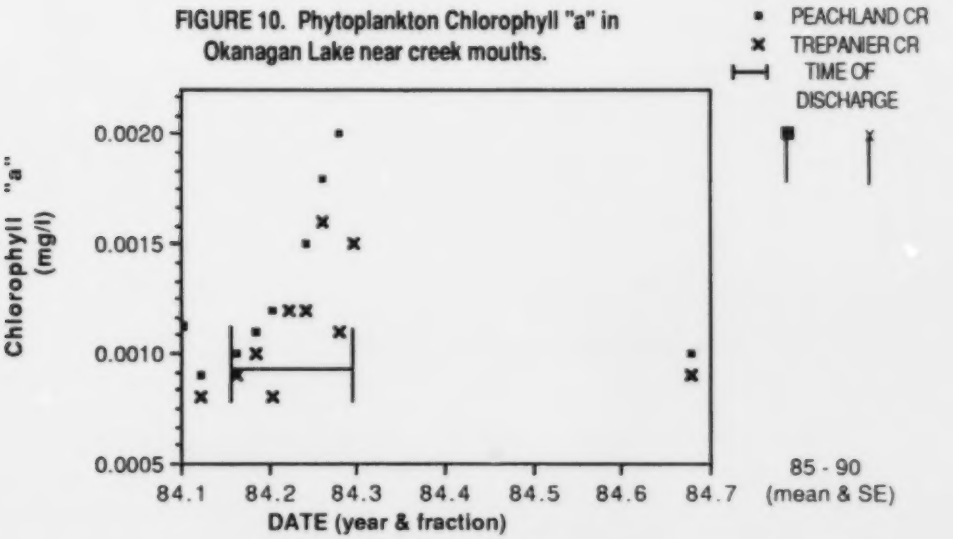


FIGURE 11. Dissolved Sulphate in Okanagan Lake near creek mouths.

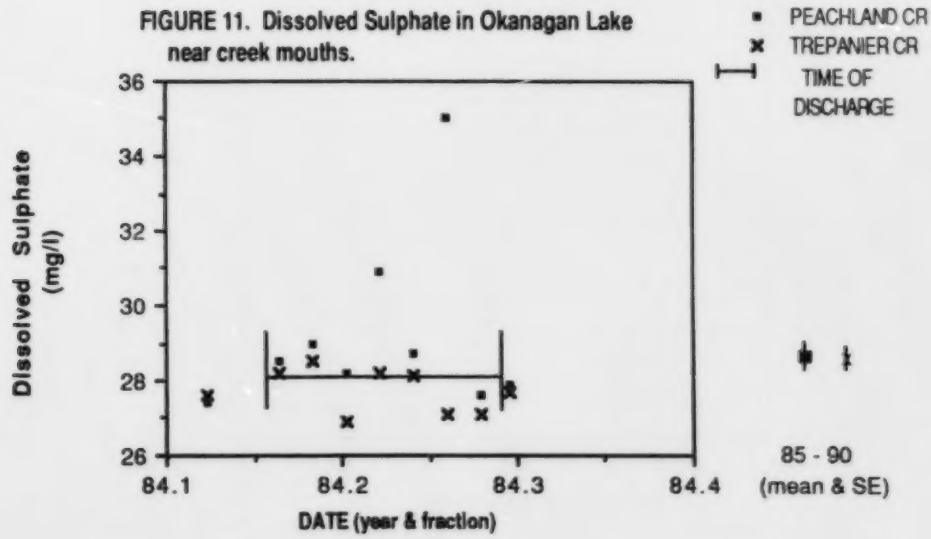


FIGURE 12. Specific Conductance in Okanagan Lake near creek mouths.

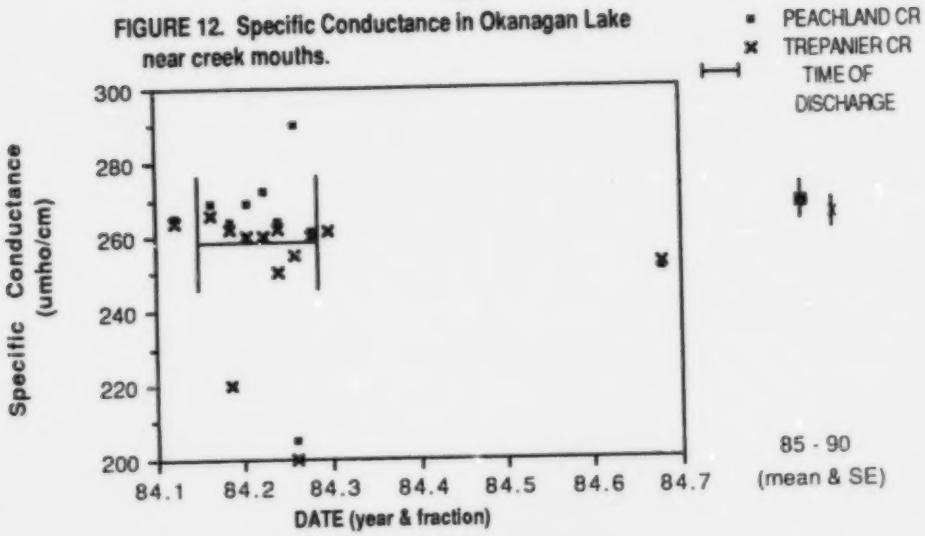


FIGURE 13. Dissolved Sodium in Okanagan Lake near creek mouths.

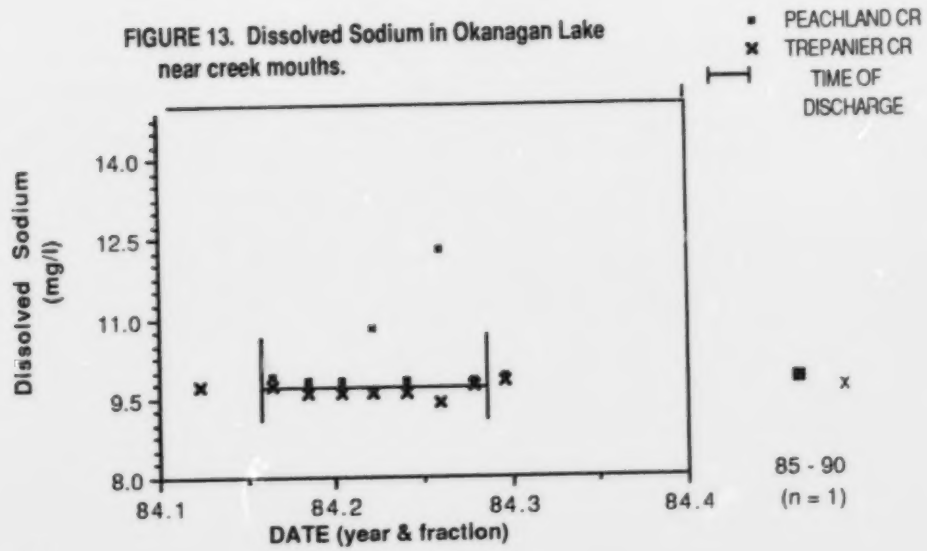


FIGURE 14. Dissolved Phosphorus in Okanagan Lake near creek mouths.

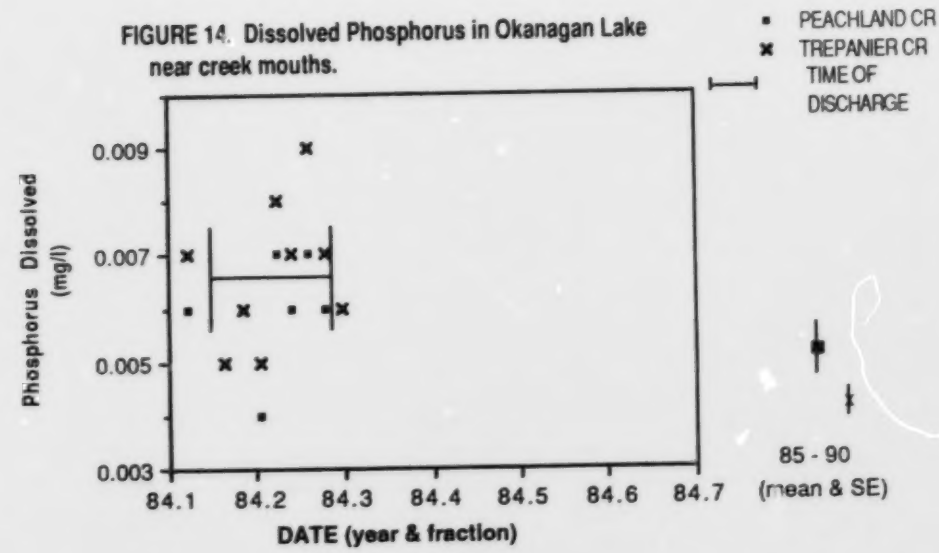


FIGURE 15. Total Phosphorus in Okanagan Lake near creek mouths.

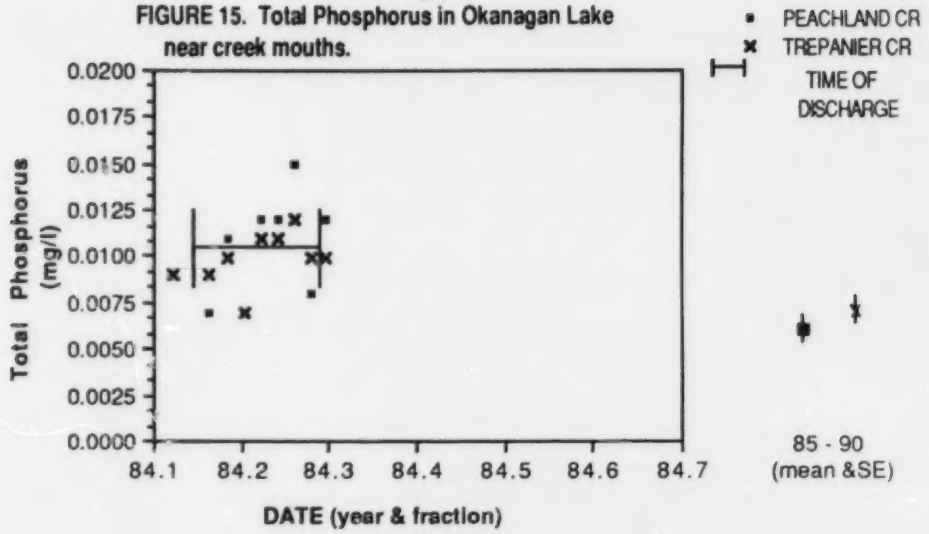


FIGURE 16. Total Copper in Okanagan Lake near creek mouths.

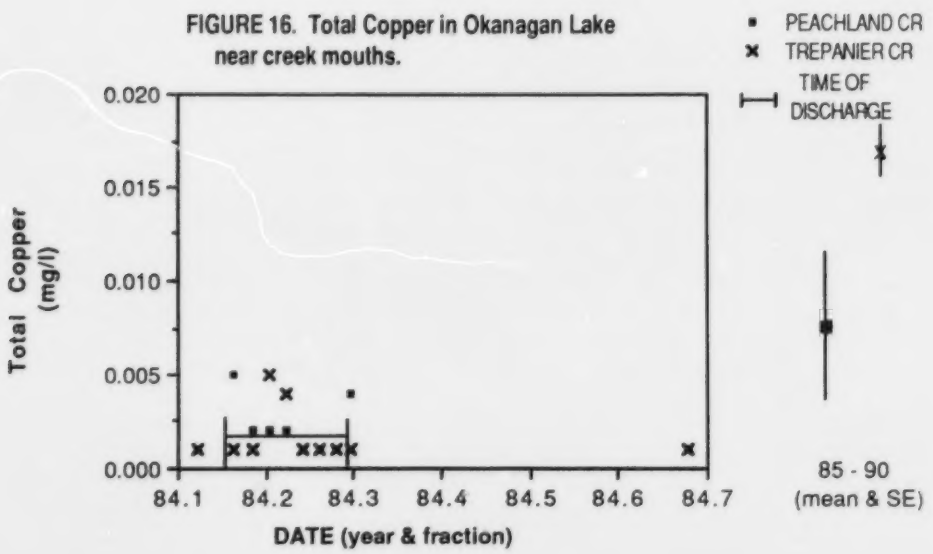


FIGURE17. Total Iron in Okanagan Lake near creek mouths.

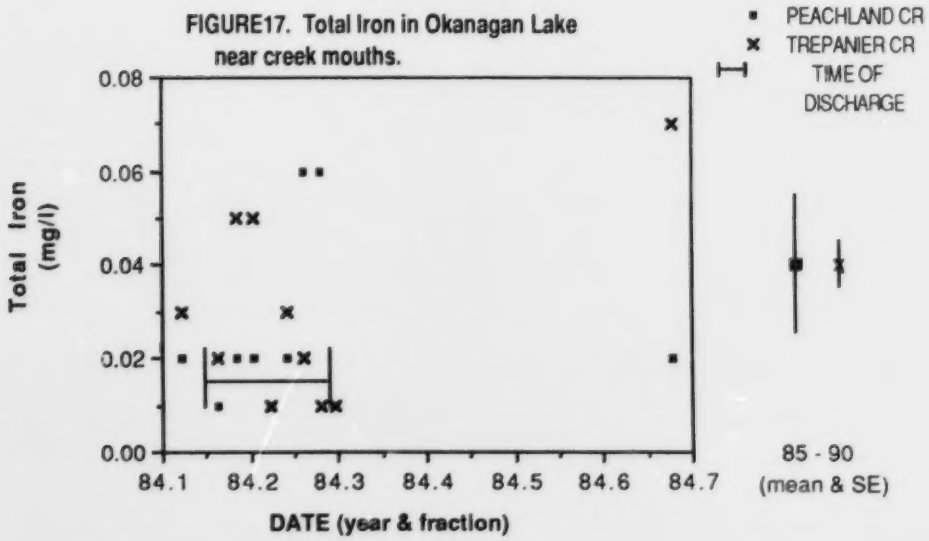


FIGURE 18. Dissolved Ammonia in Okanagan Lake near creek mouths.

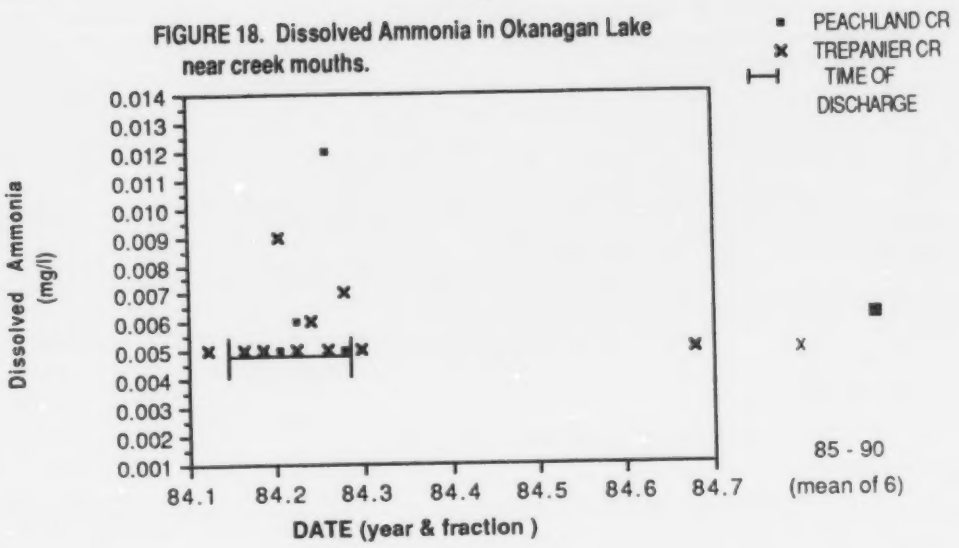
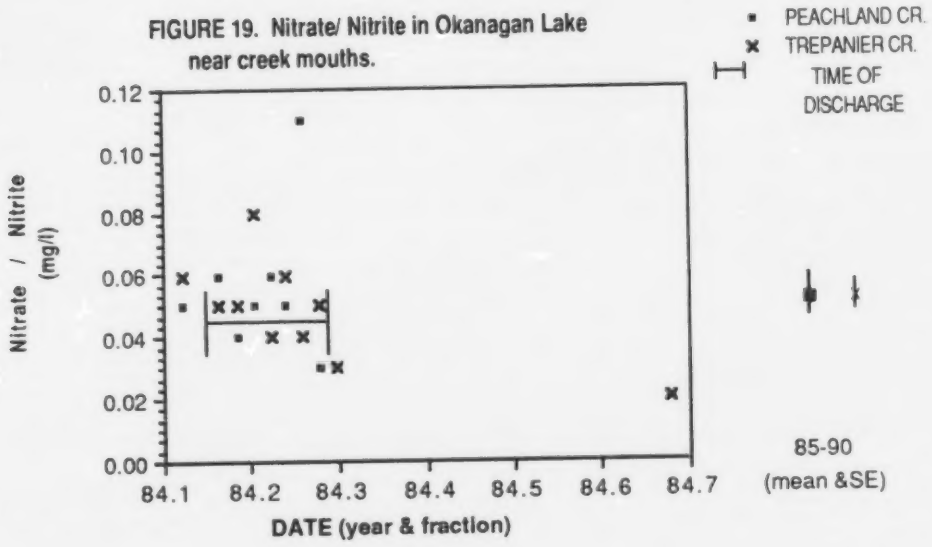


FIGURE 19. Nitrate/ Nitrite in Okanagan Lake near creek mouths.



3.0 CONCLUSIONS AND RECOMMENDATIONS

1. There is considerable seepage from the large northeast tailings dam. Although most of it is pumped back into the tailings pond, enough remains in MacDonald Creek to alter many characteristics of water quality such as total dissolved solids, molybdenum, sodium, and sulphate.

2. Although many of these characteristics in turn alter Trepanier Creek, the alteration is slight. For example, molybdenum increases only marginally downstream of the confluence with MacDonald Creek.

3. The Peachland Creek Watershed has been affected by runoff from waste rock, but not very much by tailings water. Diverting runoff into the tailings pond restored good quality to Peachland waters by reducing molybdenum and nitrate.

4. Peachland Lake had molybdenum levels of 0.3 mg/L in 1978, but they have now fallen to about 0.05 mg/L which is almost within acceptable limits for irrigation, the most restrictive quality criterion for molybdenum.

5. Brenda Mines tailings water was never found to be toxic to bacteria and only sometimes toxic to *Daphnia* or rainbow trout.

6. In Peachland Lake, trout and sucker tissue had molybdenum concentrations which were elevated compared to fish from other waters. Suckers accumulated more molybdenum than trout. The other metal concentrations appeared normal.

7. Peachland Lake fish were apparently not under metal stress from molybdenum as their anti-metal enzyme, metallothionein, was normal with respect to other fish which were stressed by high metal levels.

8. Trout living in MacDonald Creek which received tailings leachate did not have elevated metals or metallothionein.

9. It is recommended that trout and suckers in Peachland Lake be resampled to determine whether molybdenum in their tissues has decreased now that concentrations in Peachland Lake are lower.

10. Alfalfa and grass irrigated with water high in molybdenum had elevated molybdenum levels in their tissues. Levels in vegetation associated with irrigation in both Trepanier and Peachland creeks were higher than recommended without the addition of copper supplements.

11. Qualified experts should determine whether such crops are suitable for all possible uses. If not, then additional testing should be conducted to determine current conditions and appropriate advice should be given to the public.

12. Tailings water released into Peachland Creek had no toxic effects on young kokanee or invertebrates living on the stream bottom.

13. During the tailings release, there were measurable effects on some water quality characteristics of Okanagan Lake near the mouth of Peachland Creek.

14. If future tailings releases are contemplated, it is recommended that mesocosm experiments be conducted using stream invertebrate systems to determine acute and chronic effects on them and periphytic algae.

15. If future tailings releases are contemplated, it is also recommended that algal productivity experiments be conducted using Okanagan Lake water to determine whether or not micronutrients such as molybdenum stimulate phytoplankton.

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APPENDIX

Appendix Table 1

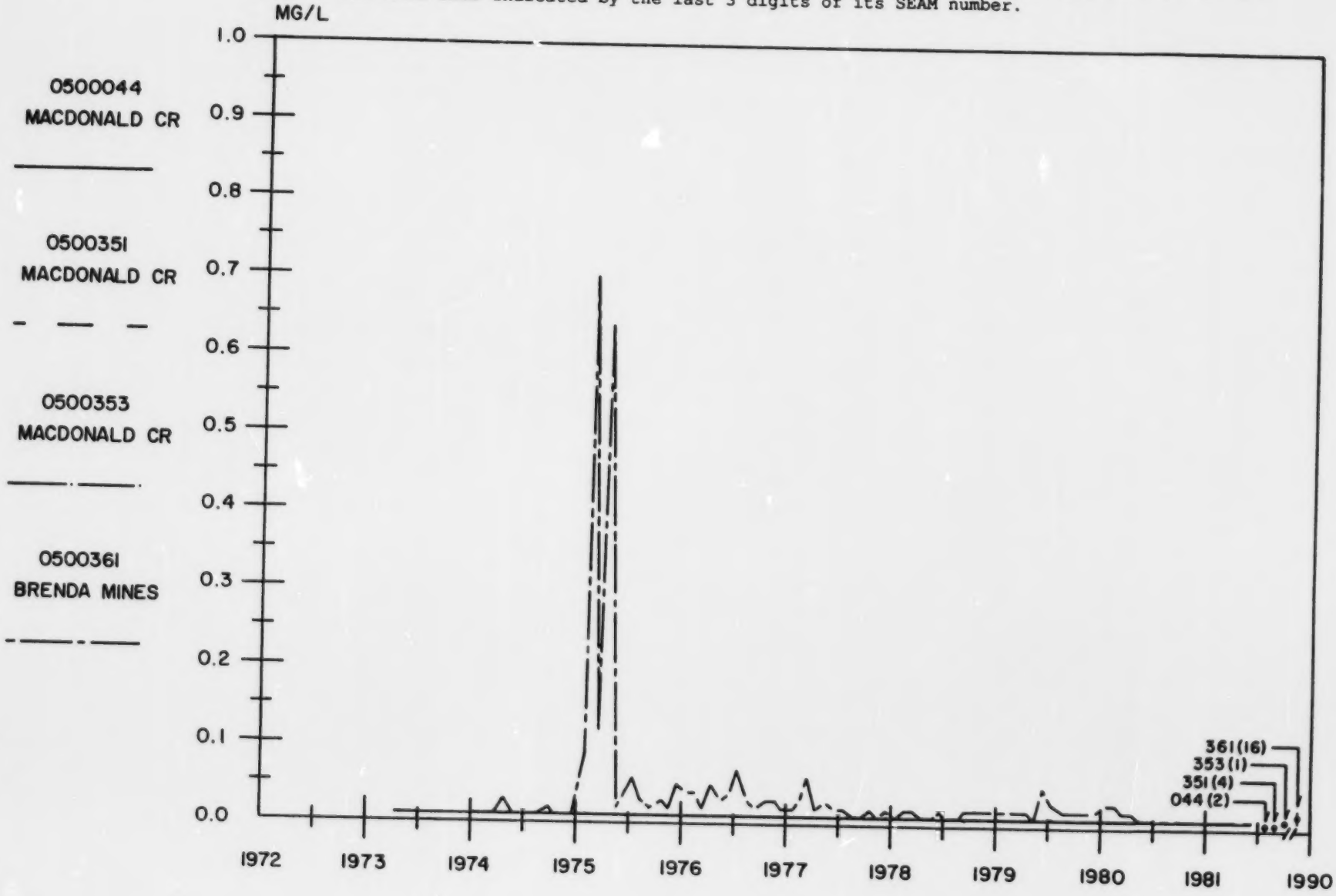
Standard errors of means for data in Table 1 for several parameters in waters around Brenda Mines from 1972 to 17 June 1990.

	PEACHLAND				BRENDA MINES	
	Creek Upstream Mine 0500354	Creek Divers. 0500355	Lake by dam 0500360	Creek Highway #97 0500056	Tailing Pond 0500358	Reclaim Reserv. 0500361
pH	0.0215	0.0287	0.0300	0.0171	0.0206	0.0242
Residue Filt	2.66	8.83	2.32	3.43	10.3	14.8
Res NF	1.07	3.29	0.859	3.27	1.19	21.9
Turbidity (ntu)	0.146	1.76	0.106	0.860	0.821	6.69
Nitrate 1109 (NO_2 + NO_3)	0.00925	0.176	0.0460	0.0316	0.168	0.0176
Phosp Tot D	0.0434	0.000425	0.00284	0.00362	0.0202	0.113
Phosp Total	0.00585	0.00156	0.00244	0.00456	0.000769	0.00275
Sulphate D	0.664	3.69	0.385	1.78	7.27	6.15
Copper (D)	0.00311	0.00318	0.000651	0.00118	0.00284	0.00812
Molybdenum (D)	0.00159	0.0106	0.00606	0.00279	0.0311	0.0439
Zinc (D)	-	0.00219	0.00398	0.00671	0.00540	0.00550

	MACDONALD CREEK			TREPANIER CREEK		
	Reclaim Reserv. 0500361	Dnstrm. Reserv. 0500044	Setling Pond 0500351	Upstrm. MacDon. Creek 0500362	Dnstrm. MacDon. Creek 0500079	Highway #97 0500078
pH	0.0242	0.0217	0.0241	0.0172	0.0173	0.0231
Residue Filt	14.8	9.15	5.65	2.50	2.59	2.40
Res NF	21.9	2.70	0.588	0.174	0.411	0.784
Turbidity (ntu)	6.69	0.241	0.272	0.116	0.106	0.0602
Nitrate 1109 (NO_2 + NO_3)	0.0176	0.0400	0.019	0.01	0.0115	0.00486
Phosp Tot D	0.113	0.108	0.238	0.123	0.0496	0.00411
Phosp Total	0.00275	0.00121	0.00469	0.00118	0.00111	0.00258
Sulphate D	6.15	3.86	3.89	0.430	0.682	0.183
Copper (D)	0.00812	0.00215	0.00580	0.00984	0.00770	0.00158
Molybdenum (D)	0.0439	0.0121	0.00556	0.00134	0.000655	0.00116
Zinc (D)	0.00550	0.00122	0.00164	0.000289	0.0190	0.00272

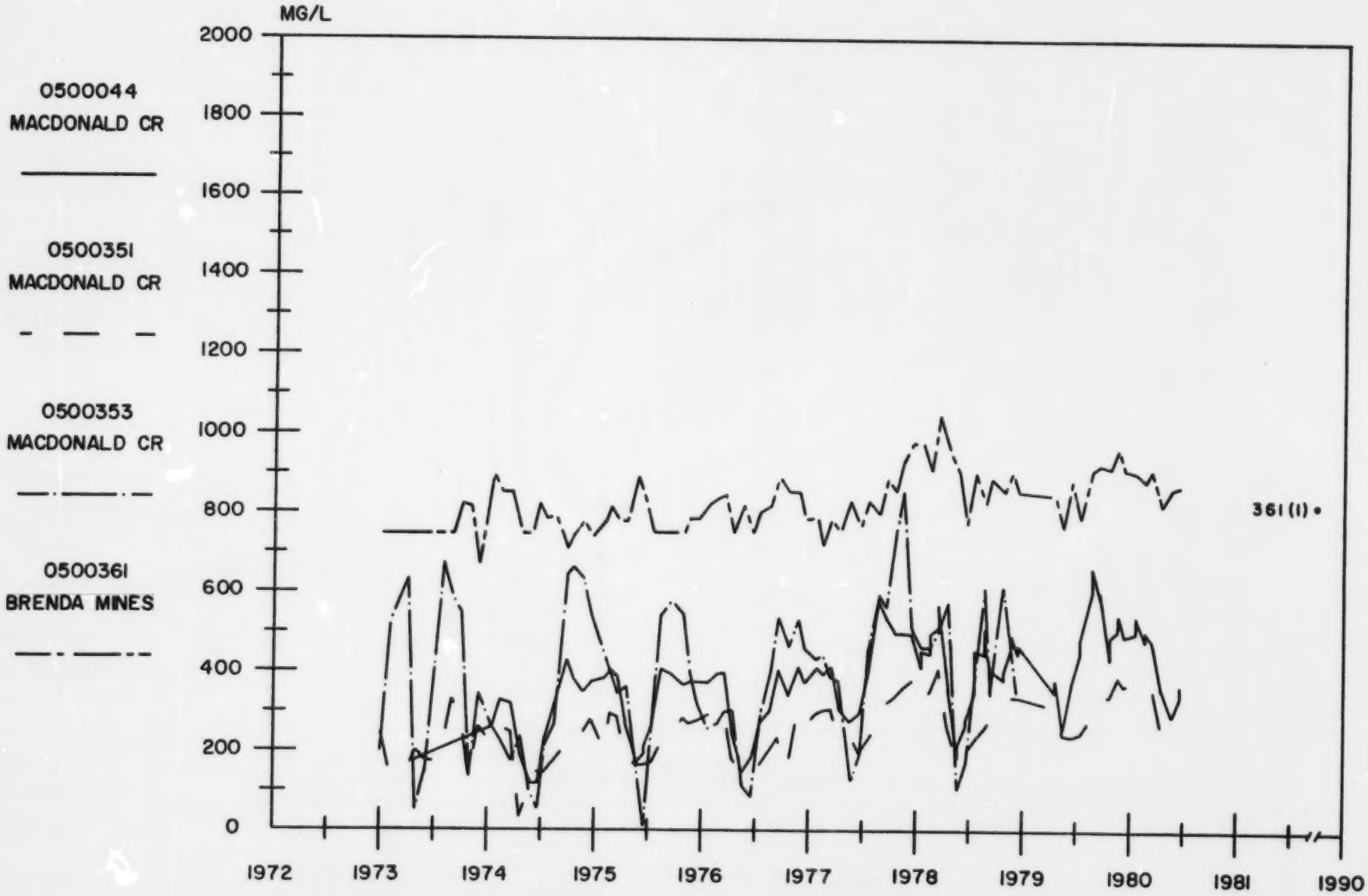
Appendix
Figure 1

Cyanide (mg/L) in wastewater from Brenda Mines and in MacDonald Cr. The solid line above the abscissa shows the data for all stations on MacDonald Cr as the values fell below the detection limit. On the far right is plotted the mean, standard error and/or sample size (n) of all data 1982-90 for each site indicated by the last 3 digits of its SEAM number.



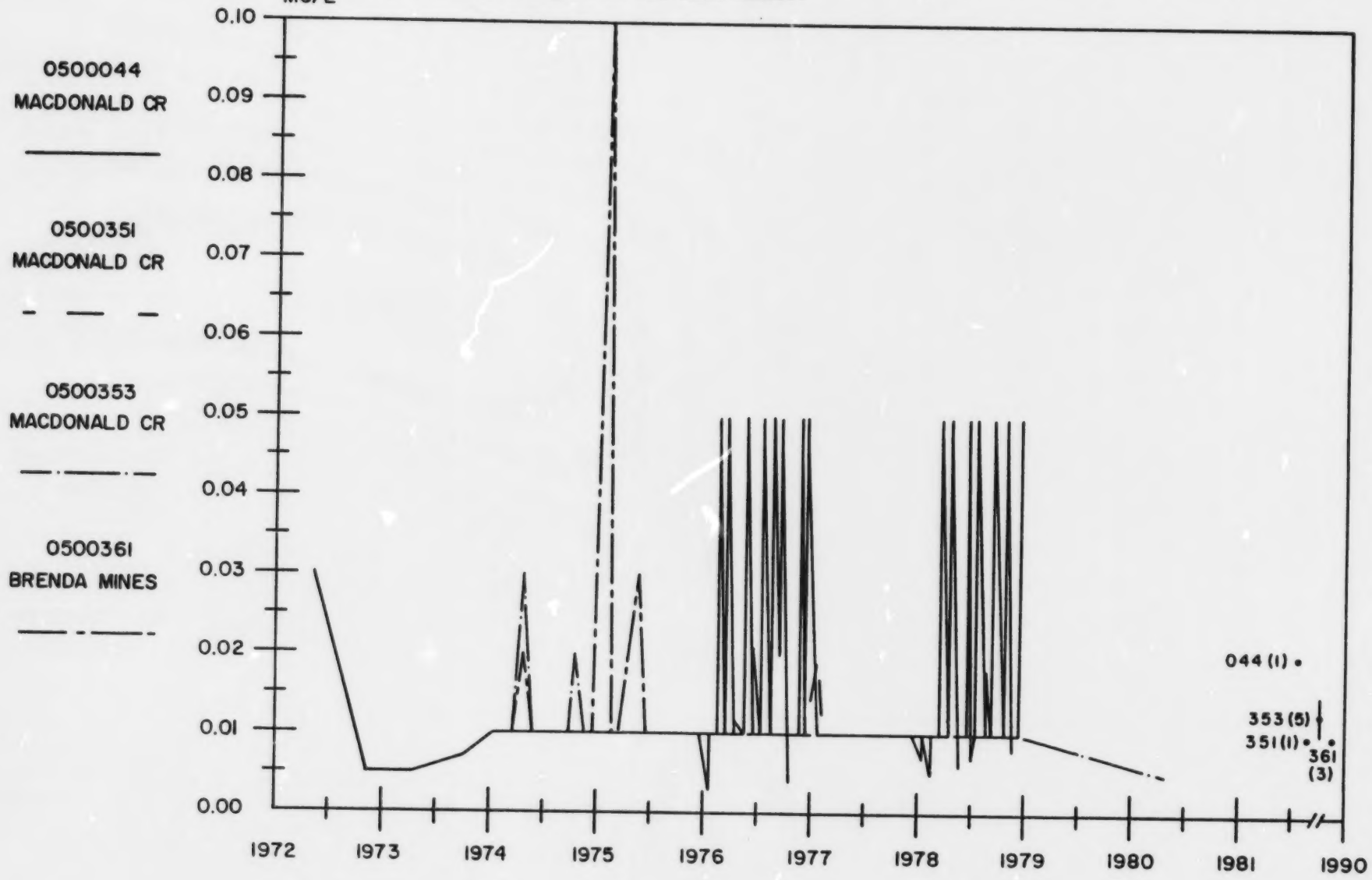
Appendix
Figure 2

Filterable residue (mg/L) in Brenda Mines wastewater and MacDonald Cr. Only one sample was analyzed after 1981; it was for Site 361 on April 19, 1982 and is plotted on the far right.

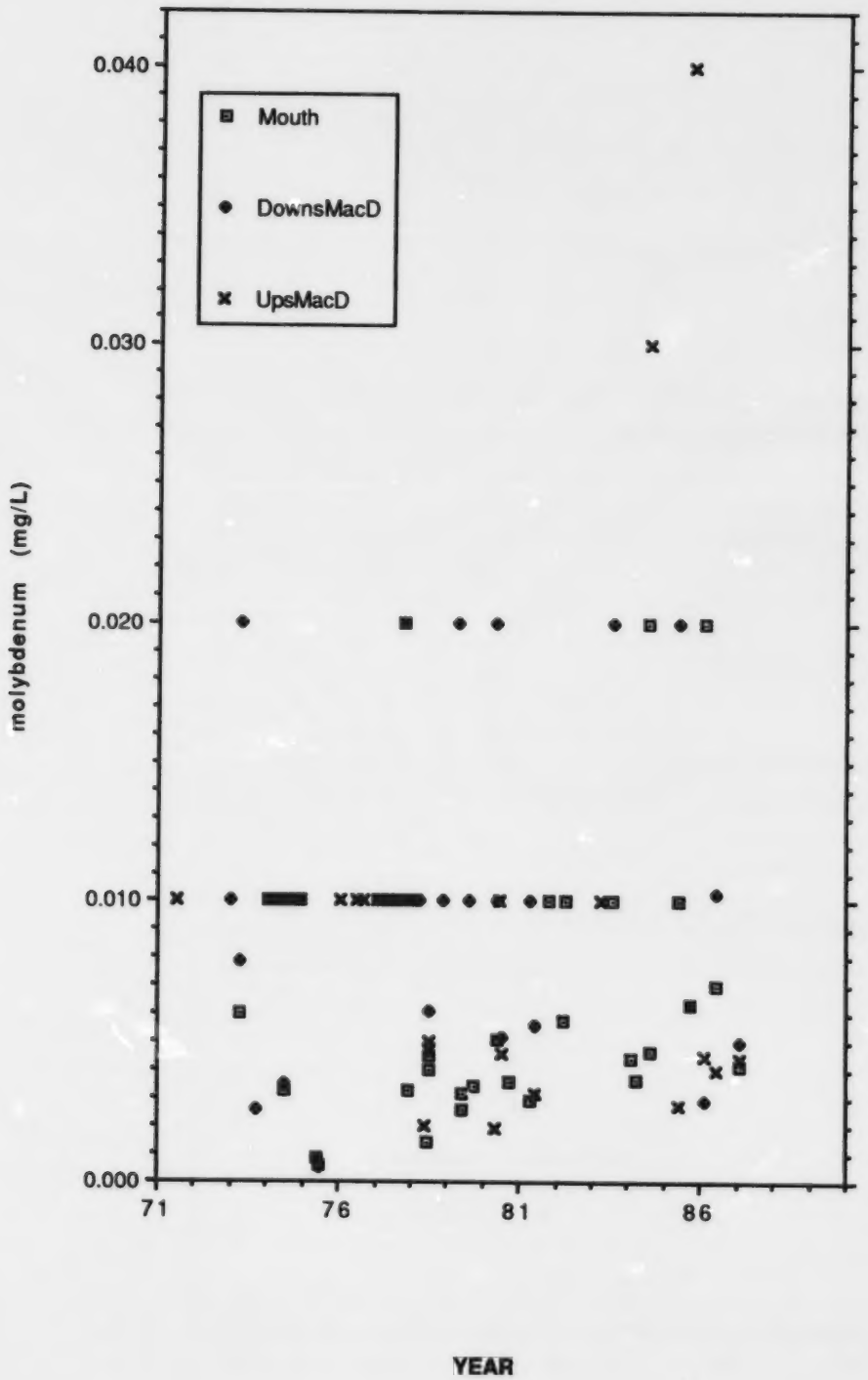


Appendix
Figure 3

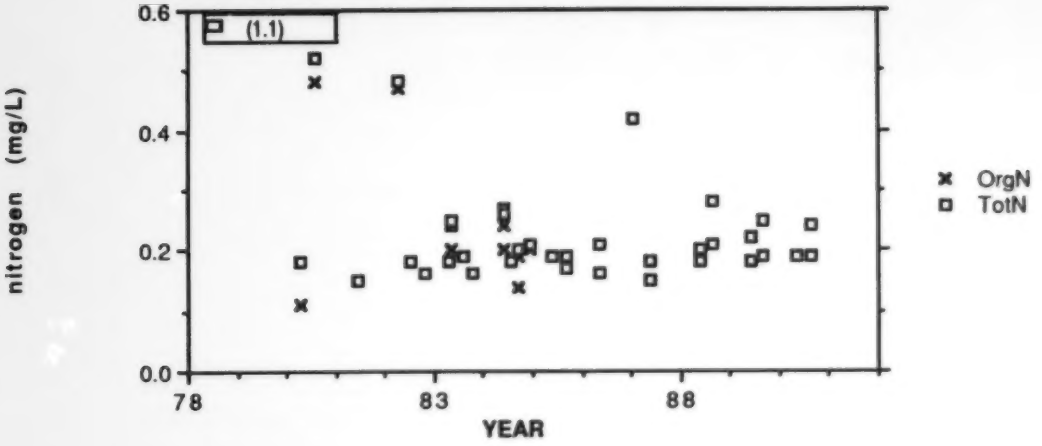
Dissolved zinc concentration (mg/L) in Brenda Mines wastewater and MacDonald Cr. Some of the plots are truncated because of changing analytical procedures with different detection limits. On the far right is plotted the mean, standard error and/or sample size (n) of all data 1982-90 for each site indicated by the last 3 digits of its SEAM number.



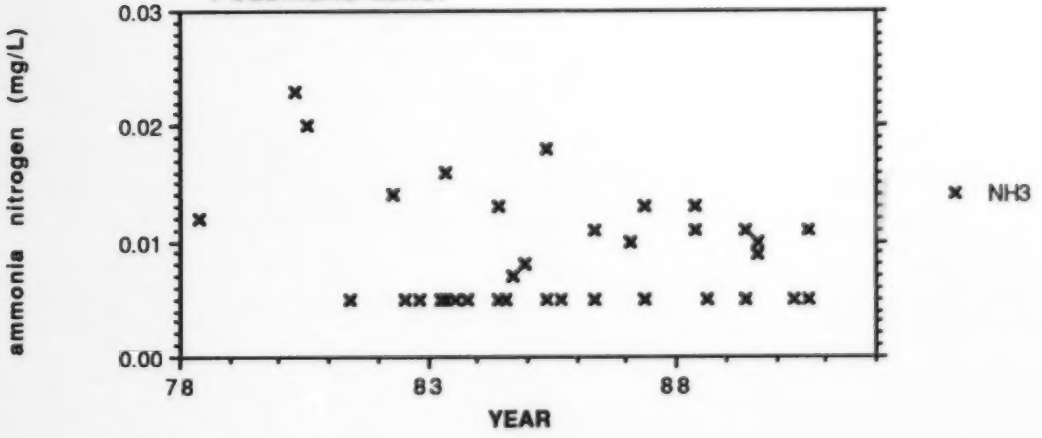
Appendix Figure 4. Dissolved & total molybdenum at 3 sites in Trepanier Creek.



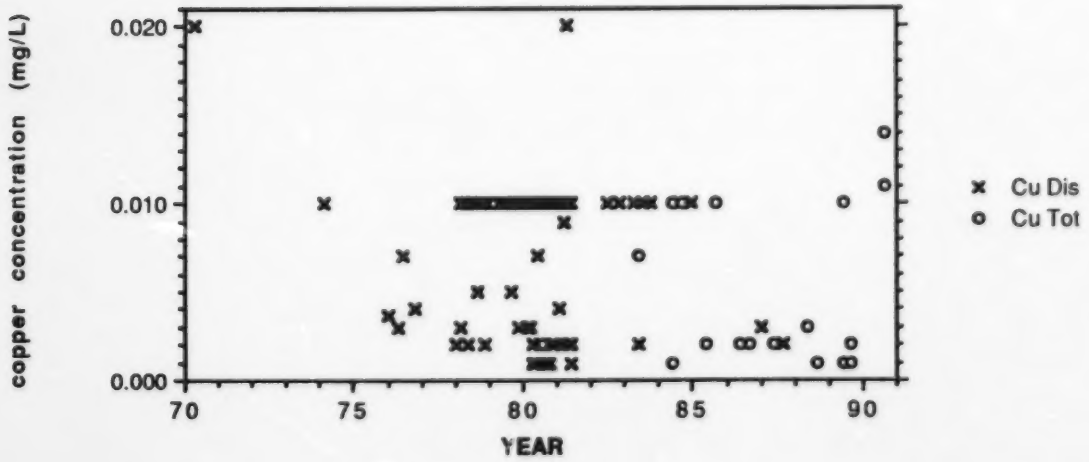
Appendix Figure 5. Total & Organic Nitrogen in Peachland Lake (no data before '78).



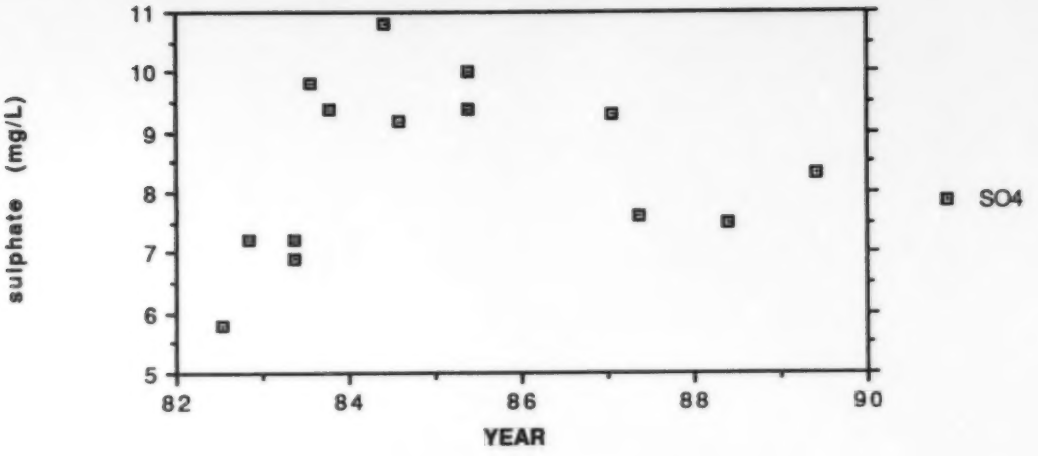
Appendix Figure 6. Ammonia nitrogen in Peachland Lake.



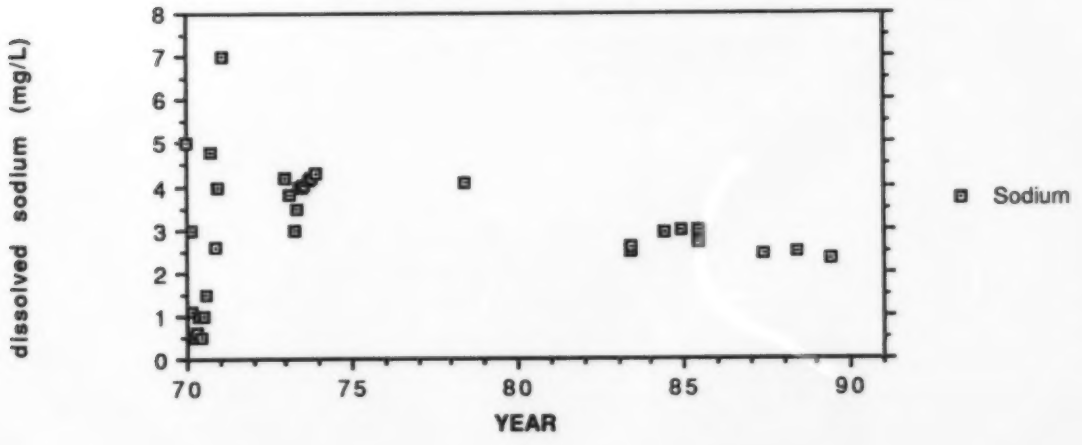
Appendix Figure 7. Copper in Peachland L.



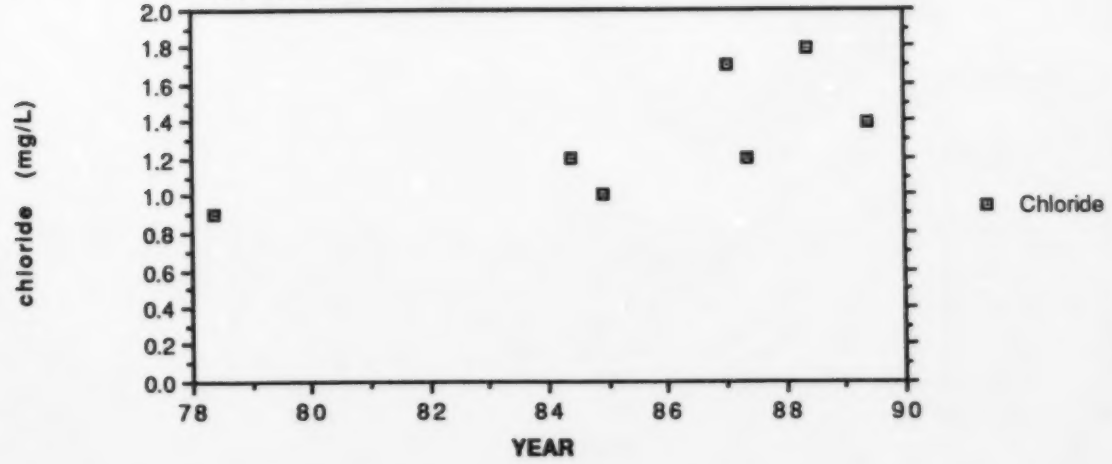
Appendix Figure 8. Sulphate in Peachland L.



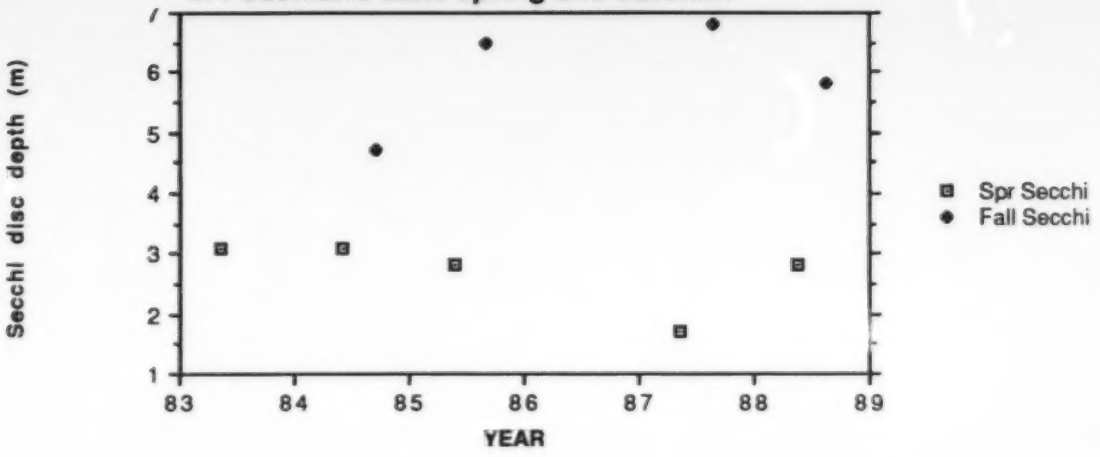
Appendix Figure 9. Sodium in Peachland L.



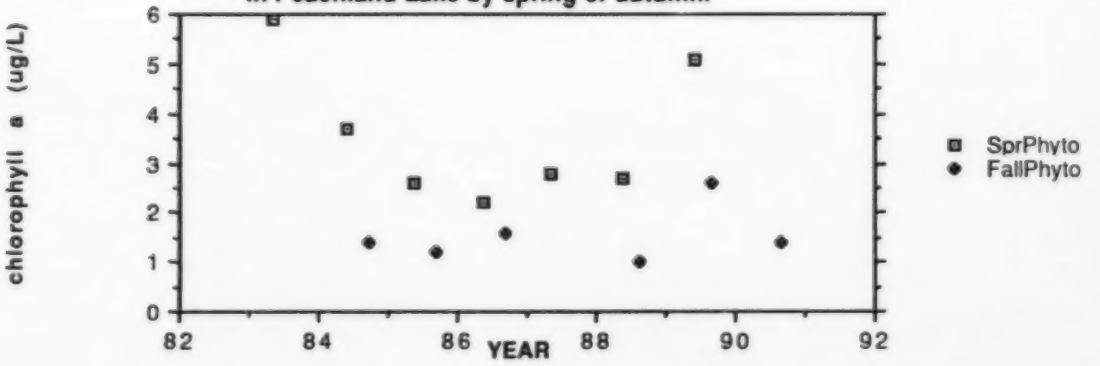
Appendix Figure 10. Chloride concentration in Peachland Lake.



Appendix Figure 11. Light extinction depth in Peachland Lake spring and autumn.



Appendix Figure 12. Phytoplankton density in Peachland Lake by spring or autumn.



Appendix Figure 13. T&D Phos in Peachland L. SprTot P is Apr-Jun vs. TotP, Jul-Mar.